

AN ECONOMIC ANALYSIS OF SOME
KANSAS CROP ROTATIONS

by

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INTRODUCTION

Several recent generations of farmers have grown up with the conviction that there is something inherently desirable about crop rotation. The term has evoked wide respect, and the practice has been eulogized by farm organizations as early as 1874, when the National Grange encouraged it by resolution.¹ More recently, the publication of a large farm organization in Kansas featured its leaders of the year and noted that five of the eight men recognized either practiced a good crop rotation, or used a legume rotation.² If you were to ask a farmer or a business man to tell you his idea of a good farmer, you are likely to hear that a good farmer is one who rotates his crops. Other criteria will be given also, but the rotation of crops is likely to rank very high on the list.

Reasons for development of this belief seem obvious. They proceed from the nature of the crops usually found in a rotation, the nature of soils, and from the historical development of agriculture, both in the Old World and in America. These reasons will not be discussed separately, but will become apparent as the study proceeds. They are based primarily on the fact that nearly all investigations of crop rotation results have been agronomic studies, with little or no economic orientation, and

¹N. S. B. Gras, A History of Agriculture in Europe and America, p. 298.

²Kansas Farm Bureau News, December 1953, p. 10.

have pointed out the benefits to the soil, which may not be transposed into farmer benefits in the relevant time period.

Crop rotation has been defined as the growing of different crops in recurring succession on the same land.¹ This definition excludes the opportunity rotations practiced by many farmers, varying with weather and price changes. However, such rotations, or crop sequences, have many of the same effects on the soil and on subsequent crop yields that planned rotations have and may not be defined out of the picture. On this subject, an early publication says, "It would be better if all writers used the term rotation of crops to designate only well laid systems or courses."² However, this advice has been poorly followed.

The Problem, A General Statement

This study was based on the hypothesis that the effects of crop rotation on a farmer are not necessarily the same as such effects on a farm. A farm is relatively timeless; a farmer is not. A second hypothesis is related to the first: some economic explanation must exist for the wide divergence between rotation recommendations and rotation practices.

The agronomic basis for crop rotation is well known. Historically, crop rotation has been credited with the control of pests and diseases, the control of erosion, and with providing

¹Soils and Men, United States Department of Agriculture Yearbook, 1933, p. 406.

²L. H. Bailey, Cyclopedia of American Agriculture, Volume II, p. 82.

nitrogen, organic matter, and improved soil condition when a legume crop is included. These benefits vary in importance with location and weather. They may be less important today than in the recent past as a result of technological advancements in chemicals for pest and weed control, improvements in fertilizers and mechanical conservation techniques, and improvements in machinery. A Kansas bulletin published nearly 20 years ago indicated that these traditional effects may have been overemphasized, even at that time.¹

Serious question concerning the need for leguminous organic matter has been raised by agronomists at the University of Illinois. They have concluded that there is probably no organic matter production problem, as such, on farms producing and returning large amounts of crop residues, even though they be non-leguminous.²

Goals and Decision Making

The problems of the farmer as a decision maker may be conveniently classified for general use into what to produce, how to produce it, and how much to produce. Solution of these problems comprises the fields of farm management and production

¹R. I. Throckmorton and F. L. Duley, Twenty Years of Soil Fertility Investigations, Kansas Agricultural Experiment Station Technical Bulletin 40, p. 54.

²W. N. Thompson, Systems of Farming Adapted to Highly Productive Level Land in Illinois, p. 107. Unpublished Ph.D. Thesis, University of Illinois, 1952.

economics. More specifically, the problems of agricultural production economics have been stated as follows:

(1) to determine and outline the conditions which give the optimum use of capital, labor, land and management in the production of primary crops and livestock, (2) to determine the extent to which the existing use of resources deviates from the optimum use, (3) to analyze the forces which condition production patterns and resource use, and (4) to explain means and methods in getting from the existing to the optimum use of resources.¹

The important question of selection of crops which is implicit in an analysis of crop rotations is a problem in production economics. If it could be limited to the objective part of that science, the problem would be greatly simplified. However, it is a fact that solutions to these problems on individual farms and for the economy exist only within a given framework of ends or goals, and to be called solutions must be oriented toward such goals.

These goals differ widely. They range from maximum profit, the goal of the firm, to maximum leisure consistent with a given level of living. Soil conservation is a widely and firmly held goal, and its adherents are quite vocal in promoting its further adoption. The use of the term "good crop rotation" should be mentioned here, since it enjoys such eminence in farm literature as a means of conservation.

Philosophers tell us that "the good" exists independent of association with matter. But crop rotation is only remotely a

¹Earl O. Heady, Economics of Agricultural Production and Resource Use, p. 12.

philosophical problem. A rotation must be good for something and for someone. It can scarcely be argued that a rotation oriented toward a remote time preference is good for a farmer who is short of cash now and expects to be short in the near future. If the rotation is actually "good", its benign effect may well go to someone other than the farmer who practiced it, since the immediate income sacrifice may have forced him to liquidate before such effects were felt.

This study has been directed toward the goal of the firm, income maximization in the decision making time period. However in the complex interrelationship that exists between the firm and the household this goal eventually becomes self limiting, since it is really only an intermediate means toward the end of better family living. After a certain level of living is reached, the utility of added income diminishes, while that of leisure increases, resulting in slackened effort toward maximum income. The goal then becomes maximum income necessary for a certain level of living, or for a fixed rate of improvement in living standards.

Despite these subjective complications, the economic problems of crop selection are appropriate for analysis. This analysis must be limited on one hand to the development or the illustration of principles which will help the farmer make his decision, and on the other hand to the specific areas where crop rotation data are available for study. The present study will not solve the crop selection problem for central and eastern Kansas farmers. The conclusions reached will apply only

in a general way to farmers in the same climatic and soil areas found at the sites from which the rotation data were taken.

It is hoped that the study might help to bring the question of crop rotation into focus, so that agronomic and economic forces may be seen in their effect on the farmer as well as on the soil.

Traditional Rotation Recommendations

The oral support given to crop rotation recommendations by non-practicing farmers and by non-farmers is not without foundation. Legume crops of various sorts were once the only available source of nitrogen, manure excepted. Today that is not the case. Many forms of supplemental nitrogen are on the market. Technological changes have been accompanied by shifts in relative commodity and factor prices, seasonally and over time.

These changes suggest a review of the crop rotation recommendations made to farmers by the research staffs at the Experiment Stations and by the Extension Services. In particular, the substitution of commercial nitrogen for organic nitrogen is a distinct and important field for agronomic and economic investigation. This is true not only in Kansas, but more particularly in the humid areas to the north and east where the complementary effect of legumes on grain production is more pronounced than it is in Kansas.¹

¹Thompson, op. cit., Ch. IX.

Evidence that this substitution possibility is not widely recognized or that little is known about it may be found in the research documents and Extension Service publications of Kansas and other stations. For example, several recent Kansas circulars have stressed the need for growing a strong legume in eastern Kansas every three to five years as a means of maintaining the nitrogen and organic matter content of the soil, to the end of high production per acre.¹

Another circular points out that, "If sufficient legumes are not grown in the rotation, then attention should be given to the use of nitrogen fertilizer, . . ."² Such recommendations contain several implications. Important among these is the suggestion that these practices are consistent with profit maximization or other goals which farmers have. Secondly these recommendations imply that farmers are able and should, in fact, turn to livestock production, as a means of increasing their income, since large quantities of forage can often be marketed only through livestock. Concerning such recommendations, Hopkins has noted that, "While this may or may not be good advice for the individual farmer, it is certainly not good advice for all the farmers of the state or nation."³ If enough entrepreneurs

¹Agronomy Handbook for 4-H Clubs, Extension Service Circular 197, Kansas State College, 1948, p. 1, and Profitable Farm Practices, unnumbered publication of the Extension Service, Kansas State College, 1948, p. 5.

²Extension Service Circular No. 200, Kansas State College, Manhattan, Kansas, p. 1.

³Cyril G. Hopkins, Soil Fertility and Permanent Agriculture, p. 226.

follow such advice, the inevitable result must be a movement away from the conditions which first prompted the recommendation.

Implicit also in generalized recommendations to grow more legumes is the hypothesis that it is more economical to supply nitrogen by the use of legumes than by use of commercial nitrogen. The opportunity cost of nitrogen produced by use of legumes can be estimated by the equation, cost equals value of grain sacrificed minus value of legume produced, minus saving in cost of production (or plus additional cost of production) of the legume. Conservation value must also be considered if erosion problems exist. There is danger in implying that the nitrogen costs nothing, because the legume is more valuable than the grain it replaces. In many cases, the value of the legume may be less than the value of the grain, depending on price ratios and the technical rate of substitution of forage for grain.

An illustration in a Kansas publication is an example of this danger. Grain crops following two years of sweet clover were reported as yielding 92.2 bushels per acre in three years. Following two years of alfalfa the yield was 86.5 bushels of grain per acre in the three years, while the grain crop following no legume yielded only 76 bushels per acre in the same period.¹ This appears to be a convincing argument for growing legumes. But the fact not considered is that two years of grain were sacrificed in growing the clover and alfalfa.

¹Agronomy Handbook for 4-H Clubs, op. cit., p. 1.

In five years, the time actually under consideration, the continuous grain rotation produced 126.5 bushels. Assuming the grain was wheat, the value was \$257 at \$2 a bushel. The value of the grain in the clover rotation was \$184 while in the alfalfa rotation grain was worth \$173. The legume rotations had a grain production disadvantage of \$73 and \$84 respectively in five years. In order for the value of the product of the clover rotation to equal the value of the product of the continuous grain rotation, leaving no net cost to the nitrogen, the value of the clover pasture or seed, plus (or minus) the savings (additions) in production costs must equal \$73 per acre in value for the five years. If the alfalfa sequence is to equal the continuous grain in value, similar conditions must hold. To the extent that the net forage value falls short of the deficit in grain production, the nitrogen must be assessed a cost.

If Kansas farmers have not responded to the constant call for increased acreage of alfalfa and sweet clover, it may well be that such action is inconsistent with one or several of the goals they strive toward. That they have not responded as well as has been thought desirable is suggested by the fact that educational efforts continue for increased acreages of legumes as a means of attaining higher income.

Rotations and Conservation

The problem of crop selection cannot be isolated from that of soil conservation. On a large part of the cultivated land in

central and eastern Kansas the farmer is faced with an apparent dilemma. He must decide his level of output and his level of conservation. To the extent that soil saving crops compete disadvantageously with soil depleting crops, the two goals of maximum output and soil conservation are in conflict.

The analysis made in this study will apply primarily to the areas of central and eastern Kansas where erosion is not a severe problem. This area includes land designated Class I by the Soil Conservation Service, described as suitable for cultivation with no erosion control measures. It might also include a large part of the acreage of Class II land, described as suitable for cultivation with minor erosion control measures.

Conclusions reached here may also apply to the land on farms in the eastern half of the state which is protected by terraces and other mechanical erosion control measures.

Such qualification does not mean that this analysis has no meaning for farmers who do have erosion problems. Farmers who weigh the value of clover or alfalfa for conservation consider the legume an input as well as a product. It may have cost as well as value.

As inputs, legumes also have substitutes. Farmers with conservation needs have a factor-factor problem. The selection of the factor or combination of factors to do the conservation job is a function of the marginal rate of substitution of the factors for each other, and of the relative prices of the factors. This problem will be discussed further in a later part of this study.

CROP ROTATION IN HISTORY

Rotation of crops has existed in some form since the earliest recorded times. Then, as now, it was an outgrowth of the problem of fertility maintenance. There appeared to be little system to the practice until the time of the Roman Empire. Gras cites Theophrastus' "Enquiry Into Plants" as evidence that legume use was known long before the time of Christ, gave way to naked fallow, and rose again with the Roman Empire. A typical rotation was fallow, grain and legume. Varro, Cato and others in the same general period have left an excellent record of crop husbandry in their time.¹

Chinese writers of the same period have also left some record of legume rotation supplanting naked fallow as population pressure increased the need for food.²

Gras credits England with finally developing a rotation system which became the model for Western Europe and America. The best known and oldest rotation was the Norfolk plan of clover, wheat, turnips, and barley. He adds parenthetically that, "Like many good things, it was overdone."³

In America, early agriculture was characterized by an abundance of new land, similar to the situation once existing in Europe and Asia. Agriculture in America went through essentially

¹Gras, op. cit., p. 32.

²Ibid., p. 41.

³Ibid., p. 183.

the same steps as it did in the Old World, but in a much shorter period.¹

At first land could be cropped until it became more profitable to claim new land than to replant the old. Later naked fallow was used, as evidenced by the Maryland system of maize (corn), naked fallow, wheat, and resting, the latter being spontaneous growth of weeds, discussed by J. B. Bordley in 1797.²

Washington in his letters to Arthur Young in England recognized the danger of such practices, and hoped "in the course of a few years, we shall make a more respectable figure as farmers than we have hitherto done."³

The use of legumes was practiced early if not extensively in America. In 1750, the advantage of preceding wheat with clover was pointed out by Eliot.⁴ In the next century numerous plans were tried as land was depleted and abandoned in the westward movement. Out of the maze of systems and ideas came a crop rotation plan for America that Gras called scientific. It was patterned after the English system, and stressed the use of legumes, discriminate crop sequence and selection, and an attempt to maximize the complementary and supplementary relationships between crops, and between crops and livestock. These latter were largely implicit, although recognized.⁵

¹Ibid., p. 285.

²Ibid., p. 238.

³Bailey, op. cit., p. 83.

⁴Gras, op. cit., p. 289.

⁵Ibid., p. 294.

These developments were not made without difficulties and mistakes. Gras cites the attempts to use English rotations, complete with turnips, as evidence of the inertia that prevailed.¹ Such inertia was certainly not confined to the 13th century.

It is interesting to note that the whole crop rotation cycle, from pre-Biblical, predatory cropping to the scientific rotation of the 19th century, developed before the nature of the soil benefitting effect of legumes was determined. Although Priestley and others wrote of the ability of legumes to utilize nitrogen from the air as early as 1774, it was not until the late 19th century that the nitrogen fixing bacteria were isolated and their role in the fixing process clarified.²

In the Agricultural Experiment Stations, rotation studies date back to the Morrow plots on the campus of the University of Illinois, established in 1876, and maintained since that time. In Kansas, rotation studies begun in 1909 are still in progress at Manhattan, and will be used in this report, along with later studies at outlying Experiment Fields.

Shortly before these early rotations were begun in Kansas, Professor TenEyck reported that rotations were not general in

¹Ibid., p. 297.

²H. E. Jones, O. W. Bidwell, and J. A. Hobbs, Lecture Notes for Soil Management, Department of Agronomy, Kansas State College, 1952, Lec. 12, p. 1.

Kansas, although a five year plan of corn, small grain and three years grass and clover was used in northeast Kansas.¹

In 1935, Throckmorton and Duley reported on the rotations at Manhattan, and noted that mention is seldom made of the fact that some rotations may be less effective in maintaining fertility and far less remunerative than continuous cropping under certain price, soil, and climatic conditions.² "Rotation of crops should not be recommended loosely, or without stating specifically what the rotation should be, or having in mind the wide differences existing between different possible rotations."³

THE THEORETICAL CONCEPTS⁴

The most general of the principles involved in the selection of the cropping system is the principle of comparative advantage. It states that a crop will be grown where its relative advantage is greatest, or its disadvantage least, rather than where its absolute yield is highest. This principle helps to explain regional specialization in certain crops. For example, corn is generally credited with a high comparative advantage in the Midwest, hence the name, Corn Belt.

If corn and wheat yield 50 and 25 bushels per acre respectively in Illinois, while in Kansas both yield 20 bushels

¹Bailey, op. cit., p. 101.

²Throckmorton and Duley, op. cit., p. 50.

³Ibid., p. 53.

⁴This discussion is based primarily on Heady, op. cit., Ch. 7-3.

per acre, the yield ratio, corn/wheat, is 2/1 in Illinois. As expected, Illinois will produce corn, because its ratio, corn/wheat, is greater than the ratio, wheat/corn.

Kansas will produce wheat under these circumstances even though wheat is at an absolute disadvantage compared with the Corn Belt. This is true because the relative disadvantage of wheat in Kansas compared with wheat in Illinois ($5/4$), is less than the relative disadvantage of corn ($5/2$). Wheat in Kansas produces 80 per cent as much as in Illinois, while corn produces only 40 per cent as much, in the example above, hence wheat has a comparative advantage. Black gives a vernacular definition of comparative advantage. "Buy anything which you can buy more cheaply than you can produce it."¹

The principle of specialization is implicit in that of comparative advantage. It has been stated as follows: "Each area or location tends to produce only a few things and to sell its surplus of these and with the proceeds therefrom buy the other things needed."²

Comparative advantage principles are useful to the farmer in deciding the combination crops to be grown but are limited in deciding the proportions in which to grow them. Differences in soil, slope, tenure, farmer preferences, and capital position complicate the solution of these problems.

¹John D. Black, Marion Clawson, Charles R. Sayre, and Walter W. Wilcox, Farm Management, p. 380.

²Ibid., p. 381.

An important set of principles related to comparative advantage and to the problem of forage production decisions may be found in the works of Weber and Von Thunen, German economists, who studied location of production with respect to markets, and location of markets with respect to the production and the physical nature of certain products.¹

The selection of the specific crops which will maximize income is a function of the level of yield, the proportion of acreage in various crops, and relative prices. The first of these determinants is a physical relationship and can be determined empirically for a given climate, soil and combination of crops.

The physical relationships most important in crop production are generally designated as complementary and competitive, although supplementary and antagonistic relationships also exist. Little is known about the extent of the complementary relationship. "One of the important tasks facing agronomists is the isolation of the cropping system which divides complementarity from competition."²

A complementary relationship exists when an increase in the output of one crop, with resources held constant in amount, results also in an increase in output of the second crop in a specified time period. This is a common relationship in crop production and results from the joint products of one or both crops, including nitrogen from legumes, improved soil condition,

¹Ibid., p. 374.

²Heady, op. cit., p. 226.

prevention of erosion and others. A complementary relationship is shown in Table 1, when 80 of the 100 total acres are in wheat and the remainder in alfalfa. It is illustrated by the line AB in Fig. 1 showing increased production of both grain and forage.

A common relationship, which may follow the complementary range, or may exist independently, is that of competition between crops at increasing marginal rates. Here each increase in the output of one product, resources held constant, requires successively larger decreases in the output of the other product. This is shown by BE in Fig. 1 where it follows the complementary range between the two crops.

Table 1. Enterprise relationships and marginal rates of substitution for some hypothetical rotations. Production figures are based on 100 acres of land.

Cropping systems ^a	: Acres out :		Total		:Marginal rate :of substitution :(lbs. grain sac- rificed per lb. :of hay gained)	
	: of 100 in :		production			
	:_____:		(lbs.)			
	:Grain :	: Hay :	: Grain :	: Hay :		
W	100	0	90,000	0	Complementary	
W(8 yrs.)A(2 yrs.)	80	20	96,000	30,000		
W(6 yrs.)A(4 yrs.)	60	40	82,800	160,000		.17
W(5 yrs.)A(5 yrs.)	50	50	70,500	200,000		.31
W(4 yrs.)A(6 yrs.)	40	60	48,000	240,000		.56
^a W = wheat, A = alfalfa.						

Table 1 shows that more grain was produced on 80 acres when a legume occupied the other 20 acres than was produced on 100 acres previously. In the range 20-40 per cent alfalfa, each pound of alfalfa gained required an average sacrifice of .17

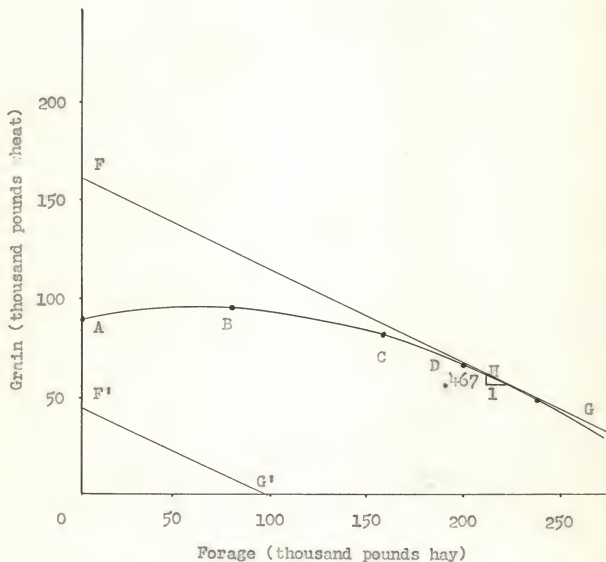


Fig. 1. Hypothetical transformation function, price ratio lines, and point where the marginal rate of substitution, forage for grain, equals the inverse price ratio.

pound of wheat. In the range 40-50 per cent alfalfa, the average sacrifice was .31 pounds wheat for each pound of hay gained, and it was .56 pounds in the 50-60 per cent legume range.

This is illustrated by the line AE in Fig. 1 representing the production of grain and hay under the various combinations in Table 1, and presumably, of all combinations within the range 0-60 per cent alfalfa, although the ranges between the known points are only estimated. Since the assumption has been made that resources are constant, this may be called an iso-resource curve, and shows various combinations of products which may be produced, given a fixed quantity of land and other resources.

The increase in grain sacrificed, from .17 to .31 to .56 pounds per pound of hay gained reflects the term "increasing marginal rates of substitution" of hay for grain.

Crops may also compete with each other at constant marginal rates of substitution. This occurs when successive, equal increases in the production of one crop result in constant decreases in production of the other. Spring barley and oats are the usual and probably the best examples of this relationship. They "(a) require the same resources and at the same time of the year, (b) they are produced at identical times of the year, and (c) do not produce by-product services which aid in the production of each other."¹

¹Heady, *op. cit.*, p. 203.

While important in agriculture, this relationship is less common than those mentioned previously, and will not enter into the following analysis.

It is obvious that over a long period of years, a farmer who is aware of his production relationships will add alfalfa to this model rotation until the complementary effect is exhausted. He would have no reason to stop at 10 acres of alfalfa, since he gets more hay and more grain by producing 20 acres of alfalfa. He could allow the hay to be burned, or simply not cut it, and still afford to produce it, since by doing so he gets more grain than when he produced no alfalfa. However, unless harvesting cost exceeds the value of the hay, it will normally be harvested. Beyond the complementary range, which is beyond 20 per cent alfalfa in the hypothetical rotation, the farmer has a decision to make. He must determine the point at which to stop adding forage acreage in competition with grain acreage, in order to get the highest income from his resources.

This point is defined by the equation $(d)\text{grain}/(d)\text{forage} = (P)\text{forage}/(P)\text{grain}$, where d = a change in production of grain or forage and P = price.¹ The marginal rate of substitution of forage for grain is $(d)\text{grain}/(d)\text{forage}$, illustrated by the line BE in Fig. 1, indicating the range in which forage and grain compete in the rotation. The ratio of hay (forage) price to grain (wheat) price is illustrated in Fig. 1 by a line FG defining all combinations of grain and hay which will yield an

¹The symbol (d) has been used throughout this thesis to represent the symbol Δ , not to denote a derivative.

equal revenue. This is called an iso-revenue curve, and its slope represents the relationship between the prices of the two products.

Line F'G', Fig. 1, represents a revenue of \$1,550, which may be realized by selling 50 tons of hay (100,000 pounds) at \$31 per ton, by selling 775 bushels of wheat (46,500 pounds) at \$2 per bushel, or by any other combination of hay and grain represented on the line F'G'. A whole family of iso-revenue curves may be drawn, representing total revenue above and below \$1,550. The objective of a farmer (firm) is to get on the highest possible revenue curve with the fixed outlay of resources. This is attained at the point of tangency of the opportunity (iso-resource) curve with the iso-revenue line, the point at which the marginal rate of substitution of forage for grain equals the price ratio, forage/grain. This is illustrated by line FG in Fig. 1, tangent to AE at point H, where by definition, the marginal rate of substitution, $(d)\text{grain}/(d)\text{forage} = \text{the ratio, } (P)\text{forage}/(P)\text{grain}$.¹ In this case, with wheat at \$2 per bushel and hay at \$31 a ton, the per pound price ratio is \$.0155/\$.0333. With $(d)\text{forage} = 1$, $(d)\text{grain} = (1)(.0155)/.0333 = .467$, the marginal rate of substitution of hay for grain at the most profitable point of operation under the given prices (Fig. 1).

With the physical relationship fixed, any change in the relative prices will call for a change in the proportions of the

¹Tangent curves have equal slopes at the point of tangency.

two crops, theoretically. However, the nature of the farming operation is such that rather wide swings in relative prices must take place before adjustments will be made. The percentage of legumes cannot be shifted from 20 to 21 to 22 per cent as prices change by a small amount.

The relationship expressed as a continuous line in Fig. 1 is actually discontinuous, as shown by Fig. 2, since only points a, b, c, d, and e are known empirically (Table 1). It is likely that rotation d, Fig. 2, would be most profitable under current prices, and with the previous assumption of equal costs for all combinations of production. If the price of grain were to rise sufficiently so that the slope of the price line fg were less than the slope of the line cd, it would be profitable to shift to rotation c, with 60 per cent grain and 40 per cent hay. If the price of grain were to fall (or hay to rise) so that the slope of fg were greater than de, it would indicate the need to switch to rotation e, 60 per cent alfalfa.

Line AE in Fig. 1 has been referred to as an iso-resource curve. It is also known as an iso-cost curve or a transformation curve. The names are based on the premise that the factors of production, and therefore, the costs of the firm are fixed within rather broad limits, and that the production pattern does not change these factors and costs appreciably within the normal decision making period.

This assumption is realistic for a large part of the costs of the farm firm. But for the variable costs it does not hold

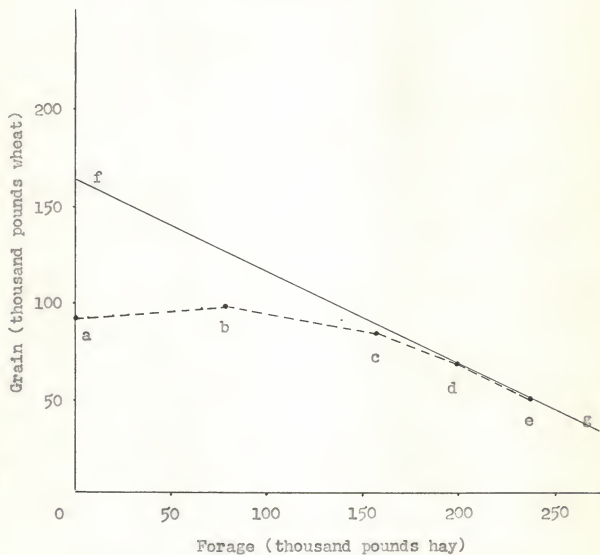


Fig. 2. Discontinuous production possibilities.

rigidly. Rather it provides a starting point from which to consider variations in cost of production.

The iso-resource or iso-cost curve may be viewed as the "opportunity cost" curve, showing cost in terms of product sacrificed, a concept mentioned earlier in the discussion of the cost of nitrogen produced by legumes.¹ The product sacrificed is looked upon as the input while the product gained is the output. In Table 1, the input in the 20-40 per cent legume range is 13,200 pounds of grain, while the product is 80,000 pounds of hay.

The condition of crop income maximization with resources fixed has been defined as the point where the marginal rate of substitution of forage for grain is inversely proportional to the price rates of the two products. Since the marginal rate of substitution over time is a function of soil, climate, variety, and other technical and agronomic factors, it may be expected to remain relatively fixed over a long period of time for a given location or area.

The same is not true of prices, which fluctuate widely, both absolutely and relative to each other. No attempt is made here to predict prices in the future.

The arithmetic mean of mid-month prices received by farmers for certain commodities in 1953 has been used in the previous pages as an aid in exposition of the principles noted. The 1953 average prices will continue to be used in this manner.

¹Heady, op. cit., p. 214.

Prices calculated in the same manner for the years 1948-1953 are listed in Table 2.

Table 2. Mean of mid-month average prices received by Kansas farmers, 1948-1953.^a

Year	: : Wheat : (bu.)	: : Corn : (bu.)	: : Oats : (bu.)	: : Grain : sorghum : (cwt.)	: : Alfalfa : hay : (ton)
1948	\$2.09	\$1.87	\$.96	\$2.83	\$21.90
1949	1.90	1.17	.70	1.83	18.20
1950	1.97	1.30	.80	1.89	18.20
1951	2.16	1.60	.94	2.19	23.70
1952	2.14	1.69	.96	2.62	31.62
1953 ^b	2.00	1.47	.81	2.34	31.00

a Based on prices received by farmers for specified commodities, "Annual Summary", Report of the Kansas State Board of Agriculture, Vol. LXVII--LXXII.

b Based on Monthly Reports, Federal-State Statistician, Topeka, Kansas, 1953.

ROTATIONS AT MANHATTAN

The study of crop rotations and their role in soil management was begun in 1909 at Kansas State College when several plots were laid out on the Agronomy Farm under the direction of W. M. Jardine, then head of the Department of Agronomy. Included in the initial program were continuous corn, continuous wheat, continuous alfalfa, and a 16 year rotation of alfalfa, four years, followed by a sequence of corn, corn, wheat for 12 years. Grain crops in this rotation were changed to corn, wheat, wheat in 1922.

Several other rotations have been studied since that time in other projects. A rotation of corn, oats, and wheat, with several combinations of sweet clover has been a part of the

wheat seedbed tests at the Agronomy Farm, while a rotation of two years alfalfa followed by corn, oats, and wheat has been included in the nitrogen fixation studies for many years.

Nearly 20 years ago Throckmorton and Duley published a summary of the results of the rotations in the soil fertility tests and some conclusions regarding rotations based on the data up to that time. Their work has been referred to previously and will be discussed further here. A significant point which does not always find its way into the academic and extension educational processes is their conclusion that:

Any shift in crop prices will cause a change in the relative value of the different cropping systems, but the fact remains that relatively high priced crops may often produce higher acre values even when grown continuously at least for a considerable time, than could be produced by rotations including crops having lower acre values.

Furthermore, it is not necessarily a fact that continuous cropping is more exhaustive of fertility or the cause of lower yields than rotation of crops.¹

Hobbs found only slight negative regression coefficients for yield of continuous wheat and corn as a function of years of such treatment. Wheat after corn and corn after wheat in a legume rotation showed a slight tendency toward increased yield but evidence was not conclusive that this was the true effect.²

Varietal changes in the period studied may have had considerable effect on yields of wheat. Wheat varieties grown

¹Throckmorton and Duley, op. cit., p. 53.

²J. A. Hobbs, The Effect of Crop Rotations and Soil Treatment on Soil Productivity, Contribution No. 493, Department of Agronomy, Kansas Agricultural Experiment Station, Manhattan, Kansas.

were changed four times from 1911-1953. Index numbers 1937-1953, for the varieties at Manhattan, and the years grown in the rotations studied by Hobbs are as follows:¹

Kharkov-----1911-1926	68
Turkey-----1927-1943	71
Tenmarq-----1944-1945	84
Pawnee-----1946-1953	100

The effects of such technological improvements have not been adjusted in this study. The effect on yield per acre would obviously tend to be counter-directional to the effect of fertility loss.

Throckmorton and Duley considered several price situations and noted that relative profitability of cropping systems was highly dependent on the price structure prevailing. They showed that at certain prices, continuous alfalfa would be more profitable than any other crop or combination of crops, while at another combination of prices, other rotations would be most profitable.²

Their analysis helps to support an argument advanced in this study, that the rotation recommendations of economists and agronomists should be tempered by the knowledge of the limitations of crop rotations. They should not be overgeneralized, nor should they appear to suggest that a rotation is a sort of sacred thing and should be practiced regardless of its consequences.

¹Unpublished data, Department of Agronomy, Kansas State College, Manhattan, Kansas.

²Throckmorton and Duley, op. cit., p. 51.

The Agronomy Farm is located about two miles northwest of the campus of Kansas State College. The soil is tentatively classified as Geary silt loam. The slope ranges from about 2 to 4 per cent.

Normal rainfall is 32 inches annually, and the normal growing season is 172 days.¹

Among the rotations studied by the Agronomy Department of Kansas State College are several which, because of their composition, are adapted to the analysis being made here. Average yields of crops in several unfertilized rotations at Manhattan are given in Table 3 for a 23 year period.

Table 3. Rotations and crop yields at the Agronomy Farm, Manhattan, Kansas, 1927-1949.^a

Rotation	Yields per acre (bu.) ^b			
	: Corn :	Oats	: Wheat :	Alfalfa (lbs.)
Continuous wheat				16.0
C-O-W	21.5	31.8	25.5	
A ^c (C-W-W) ¹²	23.7	(W) 19.9	23.1	3,217
A-A-C-O-W	25.5	42.4	28.5	3,592
Cl-Cl-C-O-W	30.6	40.2	30.5	
Cl-C-O-W	28.7	36.7	26.8	

a Data are from Agronomy Department records, Kansas State College, Manhattan, Kansas.

b Clover seed was harvested irregularly and yield average is not applicable to complete period.

These rotations will be considered in two parts, since they fall logically into rotations of grain crops with alfalfa, and grain crops with sweet clover.

¹Climate of Kansas, Report of the Kansas State Board of Agriculture, 1948, pp. 72 and 225.

Grain-Alfalfa Rotations

The first comparisons involve various percentages of alfalfa in the rotation. They are shown in Table 4.

Table 4. Enterprise relationships and marginal rates of substitution for untreated rotations at Manhattan, Kansas, 1927-1949. Production figures are based on 100 acres of land.

Cropping system ^a	Acres out of 100 in		Total production (pounds)		Marginal rate of substitution (lbs. grain sacrificed per lb. forage gained)
	Grain	Forage	Grain ^b	Forage	

Alfalfa rotations

Wheat	100	0	96,000	0	Complementary
C-O-W	100	0	103,350	0	
A ⁴ (CWW) ¹²	75	25	96,140	80,420	.15
A-A-C-O-W	60	40	77,300	143,680	.30

a C = corn, O = oats, W = wheat, A = alfalfa. Superscripts represent number of years in sequence.

b Grain is in wheat equivalent, calculated by dividing value of all grain at 1953 prices by 1953 price of wheat.

Table 4 indicates relatively low rates of substitution of hay for grain at Manhattan, at least up to the point where 40 per cent of the farm is in alfalfa. In the range 25 to 40 per cent alfalfa, the .30 pound of wheat sacrificed per pound of hay gained is worth \$.01 while the pound of hay gained is worth \$.0155 at 1953 prices (Table 2), indicating that hay production past 40 per cent may be profitable at such prices.

Another price period in Table 2 indicates a less favorable price for hay, and as a result reflects a disadvantage to the high legume rotation. In 1950, wheat was valued at \$.036 per pound while hay was valued at \$.0091 per pound. The product of the marginal rate of substitution in the range 25 to 40 per cent alfalfa (.30), times the price of grain is greater than the value of the hay gained (\$.0091), indicating that the 40 per cent alfalfa rotation would have been less profitable than was 25 per cent alfalfa at 1950 prices.

From Table 4, it may also be seen that the rotation $A^4(CWW)^{12}$ is complementary to continuous wheat, ignoring the C-O-W rotation. Slightly more grain was produced annually on 75 acres in the rotation than was produced on 100 acres in continuous wheat.

However, under relatively heavy fertilization, this complementary relationship disappeared, and the average relationship in the rather wide range, 0-25 per cent legumes was competitive throughout, as seen in Table 5. This does not mean that some complementarity may not exist when fertilizers are used. It does mean that the range may be shortened considerably by fertilization, indicating some degree of substitution of fertilizers for crop rotation.¹ It further implies that the effect of rotation when fertilizers are used is somewhat less than fully additive to the effect of the fertilizer.

¹See Heady, *op. cit.*, p. 253, for a more complete discussion of this substitution process.

Table 5. Enterprise relationships and marginal rates of substitution for two rotations with soil treatments at Manhattan, Kansas, 1927-1949.^a Production figures are based on 100 acres of land.

Cropping system	: Acres out : : of 100 in :		: Total production : : (pounds) :		:Marginal rate :of substitution :(lbs. grain :sacrificed per :lb. hay gained)
	: Grain :	: Hay :	: Grain ^b :	: Hay :	
Wheat	100	0	153,000	0	.26
A ⁴ (CWW) ¹²	75	25	123,800	110,200	

a Wheat alone received 40 lbs. ammonium nitrate, 40 lbs. potassium sulfate, 80 lbs. superphosphate until 1942, and 150 lbs. since that time. Alfalfa received 120, 90, and 190 lbs. of the respective fertilizers, corn received 55, 50 and 75 lbs., and wheat received 40 lbs. ammonium nitrate, 40 lbs. potassium sulfate, 80 lbs. superphosphate until 1942, and 150 lbs. since that time.

b In wheat equivalent.

Heady stated that fertilizers and mechanical erosion control measures may have the effect of substituting for the nitrogen input function and the erosion control function of legume crops in rotation, thus shortening or eliminating the range in which the legume is complementary to grain.¹

Yield data for the same rotations for 1911-1952 substantiate the conclusions of Tables 4 and 5, that the complementary range is either minimized or absent under treatment, even though it probably existed when no treatment was used.

One hundred acres of continuous wheat would have yielded an average of 90,000 pounds wheat, while the 16 year rotation

¹Heady, op. cit., p. 253.

would have produced 87,120 pounds grain (wheat equivalent) and 94,800 pounds hay.

Under the same treatment shown in Table 5, wheat would have averaged 136,200 pounds per 100 acres, while the rotation would have produced 110,760 pounds grain and 126,200 pounds hay.¹

Complementarity was not apparent in the longer time period as in the period 1927-1949. However, the rate of substitution between the untreated rotations was only .03 pounds grain given up for each pound hay produced, which was very nearly complementary.

The rate of substitution between the treated rotations was .20 in the longer time period.

If the relationships suggested by Heady apply here, the transformation functions in the range 0-25 per cent alfalfa may be approximately those shown in Fig. 3, which is based on Tables 4 and 5.²

Price lines CD and C'D', reflecting 1953 values of wheat and alfalfa indicate continuous advantage to the legume rotation even under treatment, while 1950 prices (Table 2), suggest a shift to a lower percentage legume under treatment, as shown by EF and E'F'.

Data were not available showing yields in the five year A-A-C-O-W rotation with the same fertilizer treatments as in

¹Yield data are from Hobbs, *op. cit.*, Table 2.

²Heady, *op. cit.*, p. 253, Fig. 8.

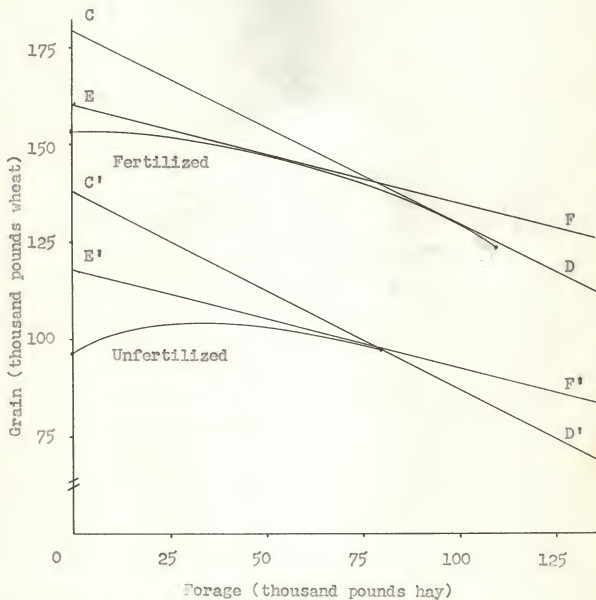


Fig. 3. Estimated transformation functions of unfertilized and fertilized rotations at Manhattan, 1927-1949.

Table 5. However if the results of such treatment were similar to the results in Table 5, it may be expected that the rate of substitution in the 25-40 per cent legume range would be quite high, and that the higher percentage legume rotation would be at a disadvantage under all but the most favorable forage prices.

Similarly, if yields were available for the C-O-W rotation under the same soil treatments, it is probable that the rate of substitution in the 0-25 per cent legume range would be considerably higher than .15, as it is in Table 4. This would point to the production of no legumes at all under price relationships considerably less favorable to grain than those which would indicate such a change in Table 4, when no fertilizer was used.

Table 6. Enterprise relationships and marginal rates of substitution for untreated rotations at Manhattan, Kansas, 1927-1949. Production figures are based on 100 acres of land.

Cropping system	:	Acres out	:			:Marginal rate
	:	of 100 in	:	Total production:	of substitution	
	:		:		:(bushels grain	
	:	Grain : Forage	:	Grain : Forage ^b	sacrificed per	
	:	:	:	(bu.) ^a :	A.U.M. forage	
:	:	:	:	:	gained)	
C-O-W	100	0	1,804	0		
Cl-C-O-W	75	25	1,569	75		3.1
Cl-Cl-C-O-W	60	40	1,385	120		4.1

a In wheat equivalent.

b In animal unit months of pasture, based on estimates made by the Agronomy Department, Kansas State College. These will be discussed more fully in a later section.

Grain-Sweet Clover Rotations

A comparison similar to that of Table 4 may be made from yield data in Table 3, involving clover rotations. Some estimates of value of clover pasture will be brought into the discussion later. Table 6 has been inserted here somewhat parenthetically, to illustrate the fact that the relative advantages of one rotation in some price period do not necessarily carry over to another rotation.

Discussion of Table 4 indicated considerable advantage to high alfalfa rotations under 1953 prices. Table 6 does not appear to support such a conclusion for clover rotations. Sacrifice of three to four bushels of wheat to produce an animal unit month of pasture would require a pasture value of \$6 to \$8 per animal unit month in order for the legume rotation to be as profitable as the non-legume rotation.

ROTATIONS IN SOUTH CENTRAL KANSAS

While rotation data were relatively abundant at Manhattan, the same was not true of other points in the state. However, at the South Central Experiment Fields near Kingman in Kingman County and near Goddard in Sedgwick County, certain rotations have been studied for several years.

The Kingman Experiment Field

The Kingman Field, now closed, was located about 15 miles east of a line dividing the eastern from the western half of

Kansas. The area is in the 26 to 28 inch rainfall belt and has a growing season averaging 194 days, 22 days more than at Manhattan.¹ In the years the rotations were under study, the rainfall was above normal as shown in Table 7.

Table 7. Rainfall amounts in specified years at the Kingman Experimental Field.^a

Period	:	Rainfall	:	Period	:	Rainfall
	:	(in.)	:		:	(in.)
1947		30.88		1951		40.54
1948		33.32		Average 1947-51		31.76
1949		32.20		Average 1932-51		26.57
1950		21.87				

^a Twentieth Annual Report, South Central Kansas Experiment Fields, Kansas Agricultural Experiment Station, 1951, Vol. XX.

The field was located on relatively level upland and consisted of a silt loam surface soil described on the Soil Conservation Service Reconnaissance Soil Survey map as a "deep, dark, reddish soil with tight clay or claypan subsoils." The slope is 0-2 per cent, and it is identified as Class II land.

Rotation I consisted of wheat, kafir, and oats with various combinations of sweet clover. Rotations including wheat, oats, and sweet clover have been used here. Results are available only for the years 1947-1951, since the rotation was changed in 1946. However, the rotation was in progress since 1945.

At the same time these rotations were in progress, wheat was grown continuously without fertilizer and with several fertilizer treatments. Results are summarized in Table 9.

¹Climate of Kansas, op. cit., pp. 93 and 225.

Table 8. Four year rotation and average yields at the South Central Kansas Experiment Field, Kingman, Kansas, 1947-1951.^a

Rotation ^b	Yield per acre (bushels)			
	:	:	Wheat	Wheat
	Oats	Sweet clover	(1st year)	(2nd year)
Oclf-C1-W-W	18.5	0.44	19.2	20.2
Ocl-C1-W-W	12.9	3.19	21.0	22.4
C1-C1-W-W	--	3.41	22.0	22.4

a Annual Report of the South Central Kansas Experiment Fields, Vol. XVI to XX.

b Oclf = Oats followed by sweet clover seeded in the fall.
 Ocl = Oats and sweet clover seeded together.
 C1 = Sweet clover.
 W = Wheat, O = Oats.

These rotations, including continuous wheat, did not comprise all the alternatives available to farmers in this area of South Central Kansas. However, they did include the bulk of crops grown. In Kingman County, for the period of the rotations, wheat was grown on an average of 80 per cent of all cropland. Important crops not included in the rotations were alfalfa, using 3.5 per cent of the cropland, and corn, using 2.8 per cent.

Table 9. Average yields of wheat per acre with different fertilizer treatments at Kingman, Kansas, 1947-1951.^a

Crop	:	Treatment	:	Yield (bushels)
Wheat		None		16.3
Wheat	25#	N. top-dressed		22.2
Wheat	25#	N. top-dressed and		
	25#	P ₂ O ₅ with seed		23.9

a Annual Report of the South Central Kansas Experiment Fields, Vol. XVI to XX.

An official total acreage of sweet clover in the county or state was not available, since reports gave only the acreage harvested for seed. However, reports put sweet clover harvested for seed in the state, 1947-51, at about 55,000 acres.¹ This was 10 per cent of the total acreage as estimated by the Extension Service.² If the proportion of sweet clover harvested for seed in Kingman County was similar to the state average as a percentage of total acreage, it may be estimated that about 10,000 acres of clover were grown in the county, since an average of 1,000 acres were harvested for seed annually from 1947 to 1951 in the county. This puts the total percentage of legumes (clover and alfalfa) in the county at about 7 per cent of all crop land.³ The acreage of other legumes was negligible.

This proportion of legumes is far below the 20 to 25 per cent often recommended to individual farmers in the county. Some explanation of the reasons for the wide difference between recommendations and practices may be found in answer to the question: What are the economic consequences to farmers who follow rotations such as are listed in Table 8? Specific answers to this question exist only on each individual farm, but an

¹Biennial Report of the Kansas State Board of Agriculture, 1947-48, 1949-50, and Farm Facts, Annual Report of the Kansas State Board of Agriculture, 1951.

²E. A. Cleavinger and L. E. Willoughby, Sweet Clover in Kansas, Kansas State College Extension Circular M-49, p. 3.

³Biennial Report of the Kansas State Board of Agriculture, 1947-48, 1949-50, and Farm Facts, Report of the Kansas State Board of Agriculture, 1951. Alfalfa acreage in the county was approximately 10,100 acres annually in the years 1947-51, while the total acreage of cropland harvested was 293,000 acres.

indication of the direction the answers will take may be found in an analysis of the experimental rotations.

It is convenient to think of the rotations in Tables 8 and 9 as including certain percentages of legumes. While they were not established with that classification, they do lend themselves to it. Subsequent references will be as follows:

Continuous wheat	0% legumes
Oclf-C1-W-W	25% legumes
Ocl-C1-W-W	37.5% legumes
C1-C1-W-W	50% legumes

This classification arises quite naturally except in the case of the 37.5 per cent designation. Here the clover was actually on the ground as long as it was in the 50 per cent legume rotation. However, during the early part of the period the clover was in competition with the nurse crop of oats. It had undisputed possession of the soil moisture and nutrients for only about 11 of the 15 months it was allowed to grow. Hence the 37.5 per cent classification is somewhat arbitrary. No data were available in the 0-25 per cent legume range.

Although the yields given in Table 8 include seed yields for sweet clover, a far greater proportion of the clover crop was harvested by pasturing, or was not harvested at all. Therefore, in determining the value of the crops grown in the rotations, estimated pasture values were used.

Estimates of the pasture available, under the several methods of handling the clover in Central Kansas were obtained

from the Agronomy Department, Kansas State College. These are given in Table 10.

Table 10. Estimated animal unit months of pasture per acre from sweet clover in selected rotations in Central and Eastern Kansas.^a

Rotation	A.U.M.		Average total A.U.M.
	Fall	Spring	
Oclf-C1-W-W	0	1.0-2.0	1.50
Ocl-C1-W-W	.5-1.25	1.0-2.5	2.60
C1-C1-W-W	.5-1.50	1.5-3.0	3.25
C1-C1-C-O-W	.5-1.50	2.0-4.0	4.00

a These estimates are considerably lower than some generalized estimates currently published, which range up to 8-10 animal unit months per acre. They were derived in cooperation with Professors Anderson and Zahnley of the Agronomy Department, Kansas State College. All are for Central Kansas except the C1-C1-C-O-W rotation.

In order to make value comparisons between rotations, it was necessary to apply some value to the sweet clover pasture. This was a difficult problem, since sweet clover replaces both native pasture and some late winter feeding. However, it is doubtful if sweet clover replaces all late winter or early spring feeding, since some dry feed must normally be fed with the succulent early clover. So the winter feeding cost, if available, could not be used alone as a clover pasture value.

In the absence of a better criterion, the average cash rental per acre of grassland in Area 6b for the year 1953 was used. This figure is \$3.85.¹ Using the accepted grazing

¹Unpublished data, Department of Economics and Sociology, Kansas State College. Original data are from Federal-State Statistician, Topeka, Kansas.

intensity of one animal unit per season on five acres, and a six month season, the value of an animal unit month in Kingman County was calculated as \$3.21, or $(\$3.85)(5)/6$.

Using this figure and 1953 prices of other products as listed previously, comparison of gross income under different rotations were made, as seen in Table 11.

Table 11. Annual gross income from grain and forage under selected rotations at Kingman, Kansas, 1947-1951, based on 100 acres of land.

Rotation	: % Legume	: Value of crop		: Gross income
		: Grain	: Forage	
Wheat	0	\$3,260	\$ 0	\$3,260
Wclf-C1-W-W ^a	25	2,955	120	3,075
Oclf-C1-W-W	25	2,340	120	2,460
Ocl-C1-W-W	40	2,423	209	2,637
C1-C1-W-W	50	2,220	261	2,481

a This is not an experimental rotation. It is inserted because it is more favorable to the rotation, and perhaps more realistic in the area. The yield for the first year of wheat is an average of the two years in the Oclf-C1-W-W rotation. It will replace the Oclf-C1-W-W rotation in subsequent analysis.

Pasture rental values from the same source previously used have been \$2.34, \$2.35, \$2.19, \$3.02, and \$3.33 in the years 1948-1952. Comparison with Table 2 will show that the forage value used in Table 11 was more favorable to forage than in any recent period. Even so, high forage rotations appear to be at considerable disadvantage.

It is apparent from Table 11 that considerable income sacrifice is inevitable on farms where this rotation relationship exists, if large proportions of the land are planted to

sweet clover and if price relationships are similar to those in the past.

This does not mean that no one will plant clover or do so profitably. Some farmers will impute a higher value to the pasture than was used here, due to their inability to lease other pasture. In some years or on some farms, clover may be more productive than in the experimental rotations. The profitability of producing the clover will depend on the transformation function of the livestock enterprise and the clover production function on the specific farm. However, either the yield of pasture or seed, or the price imputed to the clover pasture would have to be much higher than was used here if clover production in the rotation were to be as profitable as wheat produced alone. This is shown in Table 12 and illustrated in Fig. 4 drawn from Table 12.

The condition for profit maximization, production costs being equal, as has been previously stated, is that the marginal rate of substitution of y_2 for y_1 , $dy_1/dy_2 = P_{y_2}/P_{y_1}$, where y_1 = grain, y_2 = forage, and P = price. Restated, this says that the value of grain sacrificed = the value of the forage gained. From Table 12, in the case of 25 per cent legume, this becomes $4/1 = \$3.21/\2.00 , or $(4)(\$2.00) = \3.21 , which is not the case. Clearly, \$8 is greater than \$3.21, or the wheat lost is more valuable than the forage gained, indicating the need to stop short of 25 per cent legumes in a clover-wheat rotation under yields and prices as given, if income is to be maximized.

Table 12. Enterprise relationships and marginal rates of substitution for specified rotations, Kingman, Kansas, 1947-1951. Total production figures based on 100 acres of land.

Cropping system	: Acres out : : of 100 in :		: Production :		:Marginal rate :of substitution :(bushels of :wheat sacrificed :per A.U.M. pas- :ture gained)
	: Grain : Forage :		: Grain ^a : Forage ^b :		
	: : :		: : :		
	: : :		: : :		
Wheat	100	0	1,630	0	4.0
Wcl1f-C1-W-W	75	25	1,478	37.5	8.9
Ocl1-C1-W-W	62.5	37.5	1,214	67	7.3
C1-C1-W-W	50	50	1,110	81.25	

a In wheat equivalent (gross income from grain/price of wheat), 1953 prices.

b In animal unit months of pasture, from Table 10.

The marginal rates of substitution in Table 12 are average rates for rather wide ranges and are true for the points between those expressed in the table only if the relationships are linear from 0 to 25, 25 to 37.5, and 37.5 to 50 per cent legumes, which is unlikely. However, they are believed to be adequate for decision making, although shorter ranges would improve the accuracy of the estimates.

The rates of substitution for the larger proportions of legumes are even less favorable to grain than is the 25 per cent rate. They indicate that each animal unit month of pasture would have to be valued at \$17.80 and \$14.60 respectively, if the 37.5 per cent and 50 per cent legume rotations were to equal continuous wheat in value.

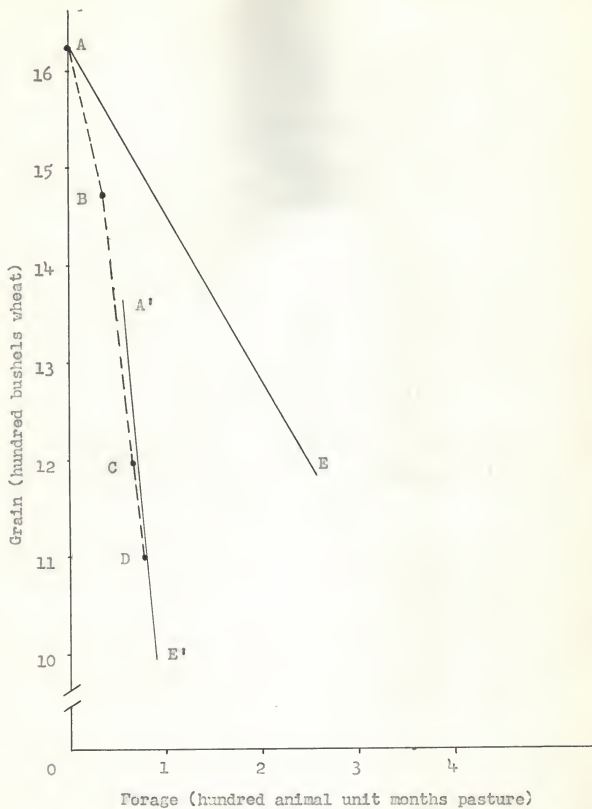


Fig. 4. Transformation functions of wheat and wheat-sweet clover rotations, Kingman, 1947-1951.

In Fig. 4, points A, B, C, and D represent combinations of grain and forage production under the four rotations as shown in Table 12. The price line AE, reflecting wheat at \$2 per bushel and pasture at \$3.21 per animal unit month, is tangent to point A, indicating that the high income combination of grain and forage is continuous wheat, at 1953 prices.

Line A'E', drawn for illustration, represents wheat at \$2 per bushel and pasture at \$20 per animal unit month, and indicates that the C1-C1-W-W rotation would be the highest profit combination if such an unusual relationship prevailed. A similar effect would be achieved by producing larger yields of clover pasture than those used in this estimate. In that case, the rate of substitution of forage for grain would be more favorable to forage production than the rates determined here.

However, the difference between prevailing relative prices and those necessary to make clover production profitable is very great. The gap between estimated pasture yields and those necessary to make clover production more profitable than wheat production at present prices is equally great. Farmers who do produce clover profitably probably enjoy some yield advantage over the experimental results and also realize a higher value from the pasture or seed produced than the average farmer can realize, thus reducing the disadvantage from both price and production standpoints.

Implicit in the previous analysis was the assumption that the yield from land continuously cropped to wheat will not fall

appreciably, and that grain yields on rotated land will not rise, but will remain at some fairly constant level above the yields from continuously cropped land.

Data from the Wichita Field affirmed this assumption. Regression of yield of continuous wheat on years, 1934-1949, yielded the regression equation $y = 21.23 + .0014X$. The value of the regression coefficient (.0014) indicates an almost constant yield on the basis of evidence available, although the change in varieties may have had some upward influence on the trend line.

The assumption that yields of grain in the legume rotation will not rise has been discussed in a preceding section (page 26).

The preceding analysis also assumed that the relevant alternatives are the growing of continuous wheat with no treatment, and the growing of grain crops in a legume rotation. This may be true for a few farmers who have no knowledge of the use of fertilizers, or who have insufficient capital to use them; but it is probably not true of the majority of farmers today. Farmers are in an excellent capital position in general, and have access to fertilizer response data. They may use fertilizer effectively if they choose to do so.

Data were not available for all possible combinations of fertilizer which might be used with wheat or with the rotation. However, an important comparison is that between the two sources of nitrogen, legumes and commercial nitrogen. Data were available for a limited comparison of this type. At the Kingman

Field, continuous wheat with 25 pounds of N. top-dressed, averaged 22.2 bushels per acre (Table 9), from 1947-1951. Gross value of the crop per acre, at the 1953 price, is \$44.40. After deducting nitrogen cost of \$3.75 an acre (\$.15 lb.), the amount is \$40.65 an acre. This is nearly \$8 per acre greater than the most favorable alternative in Table 11, continuous wheat with no treatment. It is \$10 per acre greater than the most favorable legume sequence, the hypothetical Welf-C1-W-W rotation.

Savings in production costs in the clover rotations may help to offset the advantage of continuous wheat. Accurate cost of production figures were not available, but an idea of the relative cost of growing wheat and clover may be had from the following comparison. Although the figures are not for Kingman County it is assumed that they are approximately the same as those in Kingman County, and are applicable to this analysis, since Reno County is adjacent to Kingman County.

From Table 13, it appears that the cost of producing and harvesting clover is about 70 to 85 per cent of that of producing and harvesting wheat. This represents a saving of \$2 to \$4 an acre, varying with methods of handling the clover. It does not include any charge for the greater cost of preparing the ground for wheat following clover, compared with wheat after wheat, which may exist in some years.

The cost of growing clover may now be viewed as the amount of wheat sacrificed in producing the clover, less the additional cost of producing the wheat. For the untreated rotations previously discussed compared with continuous wheat with 25 pounds

of nitrogen, this cost is shown in Table 14. Data were not available for the rotations with soil treatments.

Table 13. Estimated cost of production per acre of wheat and sweet clover, Reno County, Kansas.^a

Tillage operation	:	Wheat	:	Oats with clover	:	Clover	
						Seeded alone	Seeded with oats
Plowing		\$ 2.40		\$1.20		\$ 2.40	\$1.20
Discing	(2)	2.50	(.5)	.63	(1)	1.25	(.5) .63
Harrowing	(2)	1.00	(1)	.50	(1)	.50	(1) .50
Drilling		1.00	(.5)	.50		1.00	(.5) .50
Harvesting		3.45		3.45		3.00 ^b	3.00 ^b
Seed	(1 bu.)	2.50		1.20 (12 lbs.)		3.00	3.00
Total		\$12.85		\$7.48		\$10.95	\$8.83

a 1952-53 Custom Rates for Farm Operations in Central Kansas, Kansas Agricultural Experiment Station Report Number 60, Nov. 1953. Land costs are not included.

b This estimate may be high since it often appears to cost nothing to harvest clover by pasturing. Fencing, watering, and the need to exercise caution in grazing clover are the main elements in this cost figure.

Table 14. Estimated opportunity cost of production of sweet clover in Kingman County.

Rotation	:	%	:Gross : :income:	: Gross income : : sacrificed	: Per acre : : saving in:	:net oppor- :tunity cost
	:	:	: per : : acre :	: per acre : : production:	: production:	: cost ^b : : production
	:	:	:	: \$44.40 - Col. 3:	:	:
Welf-C1-W-W	25		\$30.75	\$13.65	\$.50	\$13.15
Ocl-C1-W-W	37.5		26.37	18.03	2.35	15.68
C1-C1-W-W	50		24.81	19.59	3.65	15.94

a From Table 11.

b From Table 13.

Table 14 indicates that if nitrogen in one form or another is to be used, the cost of producing organic nitrogen in terms

of wheat sacrificed varies from about \$13 to \$16 per acre. This figure is per rotation acre, not simply per acre in clover, and is a recurring cost each year, as is the cost of commercial nitrogen. From this we may infer that the cost of commercial nitrogen necessary to produce 22.2 bushels per acre under conditions prevailing at or near the Kingman Field (25 lbs. N.) must rise to \$13.15 before it becomes equally as profitable to produce organic nitrogen by use of a 25 per cent clover rotation as to apply commercial nitrogen on continuous wheat. Similarly the cost of 25 pounds of nitrogen must rise to \$15.68 to permit producing 37.5 per cent clover, and to \$15.94 to encourage use of the C1-C1-W-W rotation.

Lower Ranges of Legume Production

Although data were seriously limited, it appeared worthwhile to speculate about the economic effects which might accrue under some legume wheat rotations in which the proportion of legumes is very low, since the high percentage legume (clover) rotations appear to be costly in terms of wheat sacrificed.

To do this it was necessary to make some estimate of the yield of wheat which would occur in the rotation with the legume percentage in the 0-25 per cent range. From Tables 8 and 9, the per acre average yields of wheat at Kingman under various percentages of legumes are as follows:

0% - 16.3 bushels	37.5% - 21.7 bushels
25% - 19.7 bushels	50 % - 22.2 bushels

From these, a linear regression equation of the form $y = a + bx$, was calculated, in which y is yield in bushels per acre, x is a unit of clover (12.5 acres per 100 acres) considered as an input, a is the yield of wheat when no legume is grown, and b the slope of the regression line (bushels of wheat gained per acre in wheat, per unit of legume added).

This is illustrated in Fig. 5, in which $a = 16.49$, $b = 1.55$, and the regression equation is $y = 16.49 + 1.55x$. The regression line AB indicates the expected yield of wheat per acre in the range 0-50 per cent sweet clover in the rotation, as predicted by available data. Analysis indicated that the true slope of the regression line is between .30 and 2.80 at the 98 per cent confidence level. Restated this says that we may be 98 per cent sure that the yield of wheat per acre will rise between .30 bushels and 2.80 bushels with each unit (12.5 per cent of cropland) of clover added to the rotation, on the basis of the data.

If actual yield per acre under various levels of the legume were equal to those predicted by this linear function, the relationship between grain and forage would be competitive throughout at a constant rate, and production decisions would be made by relative prices alone at some level, 0-100 per cent legume, probably at either extreme of that range.

However, since there are no known exceptions to the law of diminishing returns, we may assume that the yield per acre is some curvilinear function of the percentage of legumes in the rotation.

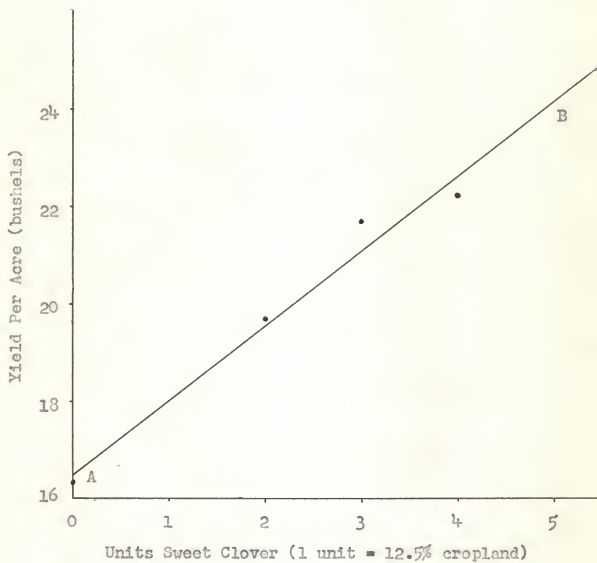


Fig. 5. Regression of yield per acre of wheat on percentage cropland in sweet clover.

Data were not available to derive this function mathematically. Little more can be done than to sketch a free hand curve and to consider the grain-forage relationship if yield were an approximate function of that curve.

In Fig. 6, line AB is such a curve, and characterizes a production relationship in which diminishing returns hold throughout all input ranges. No data were available to indicate that this relationship exists in Kansas wheat production, although some fertilizer studies have indicated that the production function of wheat with nitrogen fertilizer has an extremely short range of increasing returns, if any exists at all.¹ Heady states that "For all practical purposes, the soil production function is of a diminishing-returns nature throughout."²

If the relationships illustrated in Fig. 6 were those actually existing in clover-wheat rotations, the yields, total production and marginal rates of substitution would be those shown in Table 15.

This is shown graphically in Fig. 7, in which animal unit months and pasture value have been put on an animal unit week basis to facilitate exposition. Tangency of the 1953 price line GH, with the transformation curve at point C, representing production of about 10 per cent clover simply restates the fact that at any point beyond 10 per cent of cropland in sweet clover,

¹Unpublished data, Department of Economics and Sociology, Kansas State College, Manhattan, Kansas.

²Heady, op. cit., pp. 62-63.

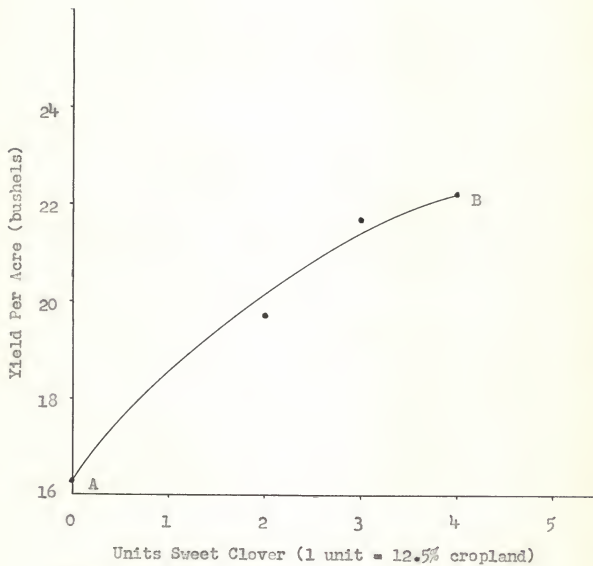


Fig. 6. Estimated wheat yields at Kingman.

Table 15. Hypothetical yields per acre, enterprise relationships, and marginal rates of substitution of forage for grain, Kingman County, Kansas.

Per cent legume	Yield per acre	Production per 100 acres of cropland	Marginal rate of substitution (bush-els of wheat sacrificed per A.U.M. pasture gained)
:	:	Wheat : A.U.M. : (bu.) : pasture ^a	:
0	16.3	1,630	0
5	17.3	1,644	8
10	18.2	1,638	15
15	18.8	1,598	23
20	19.5	1,560	30
25	20.1	1,508	38

a Based on the estimates in Table 10.

forage competes disadvantageously at 1953 prices, even though they are relatively favorable to forage. Consequently, clover production should stop at about 10 per cent of the cropland, if the land is to be used most profitably.

When the relationship postulated in Fig. 7 exists, the production of organic nitrogen in the very low range of legume percentage may be more economical than the addition of commercial nitrogen. The complementary range, which was both short and unpronounced in Table 15, will be referred to here as within the range 0-10 per cent legumes. In this range, the nitrogen cost is negative, since more grain may be produced than was produced with no legumes, and at a cost approximately equal to the cost of wheat production. At the 15 per cent legume level the cost of nitrogen has become positive as indicated

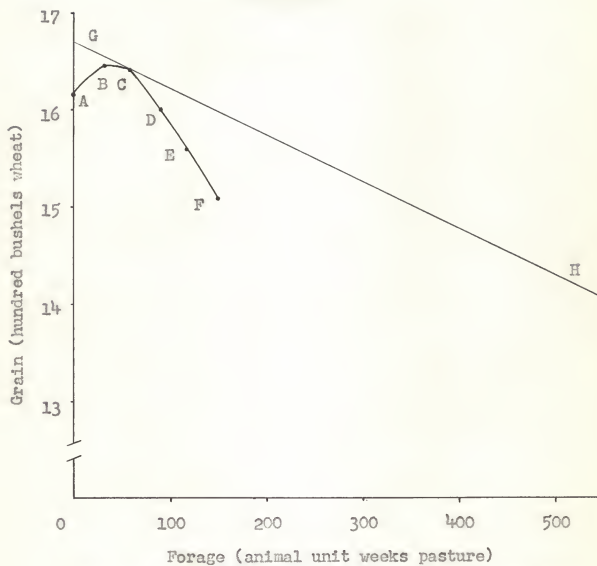


Fig. 7. Transformation function estimated from Table 15.

by the fact that the value of wheat lost (\$10) is greater than the value of pasture gained (\$3.21), by about \$7. If the forage gained is viewed as marginal revenue and the wheat lost as marginal cost, it will be apparent that the inputs (clover) have gone beyond the point of maximum profit and should be reduced.

This sets a limit to the extent of organic nitrogen production, a limit which is applicable if no other form of nitrogen exists, or at least will not be used by the operator. The economic limit of such production may be quite different in the presence of nitrogen substitutes.

Heady stated that when nitrogen is provided in manure or by commercial fertilizer, the complementary range may disappear and the crops will be competitive throughout all ranges.¹ This is borne out by Kansas data, although only roughly due to the inadequacy of the data, and has been discussed previously.

The Wichita Experiment Field

The Wichita Experiment Field, also closed, was located approximately two miles east and one-half mile north of Goddard, in the center of Sedgwick County, and about eight miles west of Wichita. The soil has been described as a "deep, dark reddish soil with friable or moderately friable, silty to clayey subsoils", by the Soil Conservation Reconnaissance Soil Survey. It is an upland soil. This soil type is a prominent one in the

¹Heady, op. cit., p. 253.

county, and has been classified tentatively as Albion Silt Loam. The slope of these soils varies from 0 to 7 per cent in the county. Slope on the experimental field site was negligible.

The field lies in the 28 to 30 inch rainfall belt of Kansas. However, the average precipitation from 1932-1950 averaged 30.03 inches while that of 1942-1950 averaged 32.34 inches. Yearly averages are shown in Table 16.

Table 16. Annual average rainfall at the Wichita Experiment Field for specified years.^a

Year	:	Inches	:	Year	:	Inches
1942		42.70		1947		30.40
1943		22.98		1948		33.45
1944		43.75		1949		35.47
1945		31.18		1950		27.16
1946		23.93		1932-50		30.03

^a Nineteenth Annual Report, South Central Kansas Experiment Fields, Kansas Agricultural Experiment Station, 1950.

Rotations tested in Sedgwick County included the most important crops of the area. Wheat was again the primary crop, having been seeded on an average of 59 per cent of the cropland in the period 1947-1951. In the same period corn occupied 9 per cent, alfalfa 10 per cent, and oats 8 per cent of the cropland. Total acreage of legumes can only be estimated since the reports include only the portion of sweet clover harvested for seed.

If the Sedgwick County 1947-1951 average of 1,500 acres of seed harvested annually were in the same proportion to total acreage as the previously estimated state average, the county may have had nearly 15,000 acres in sweet clover, or 3.8 per

cent of the total cropland. This plus the 10 per cent of cropland in alfalfa would give the county nearly 14 per cent of cropland in legumes.¹ However, one cannot assume from this that large numbers of farms practiced a strong legume rotation, since a large part of the county is composed of the flood plain of the Arkansas River, on which alfalfa production is heavy.

Table 17. Enterprise relationships and marginal rates of substitution for two rotations in Sedgwick County, Kansas, 1933-1950. Based on 100 acres of cropland.^a

Rotation	: Acres out		: Total production		: Marginal rate of
	: of 100 in				: substitution
	: Grain	: Hay	: Grain ^b	: Hay	: (pounds grain
	:	:	:	:	: sacrificed per
					: pound hay gained)
Wheat	100	0	122,400	---	
A ⁴ (S-O-W) ¹²	75	25	78,900 ^c	72,000	.60
			(101,000) ^d	(72,000)	(.30)

a Nineteenth Annual Report, South Central Kansas Experiment Fields, Kansas Agricultural Experiment Station, 1950.

b In wheat equivalent, value of grain/price of wheat.

c No value imputed to the sorghum stover.

d. A value of \$5 per ton imputed to the stover, and added to grain equivalent. The MRS (.30) refers to the substitution ratio between lines 1 and 3.

Rotation one at Wichita was a 16 year sequence in which alfalfa was grown four years on each of four plots, with atlas sargo, oats, and wheat completing the cropping system. Per acre yields for this rotation for the years 1933-1950 were

¹Reports of the Kansas State Board of Agriculture, op. cit., 1947-1951.

wheat 25.6 bushels, oats 36.1 bushels, sorghum 18.9 bushels of grain and 5.9 tons fodder, and alfalfa, 1.44 tons hay. Continuous wheat was also grown without fertilizer treatment during this period. The average yield was 20.4 bushels per acre.

Table 17 and Fig. 8 show that at the price ratio given, the critical factor in determining the maximum profit rotation is the ability of the operator to utilize the sorghum stover effectively. It may appear useless to discuss such a problem in a year of drought and feed shortage, when everything produced can be fed or sold. But this is not usually the case. Nor would it be the case if the grain in the rotation were milo, and the grain yield was the same while the forage value was negligible.

Points A and B, Fig. 8, represent the combinations of production when no value was imputed to the stover. Point C represents the relationship to A when the stover was valued at \$5 per ton. Line DF, reflecting the 1953 price ratio for wheat and alfalfa hay, is tangent to C, indicating that profit would be maximized by the legume rotation if the stover were worth as much as \$5 per ton. However, the price line D'F', tangent to A, represents a higher income than its parallel which would be tangent to B, the rotation gross value when the stover has no use (value). In that case, continuous wheat would be superior in income to the rotation.

The previous analysis has been made with the assumption of equal production costs for all combinations of forage and grain. This is scarcely the case, since alfalfa under most

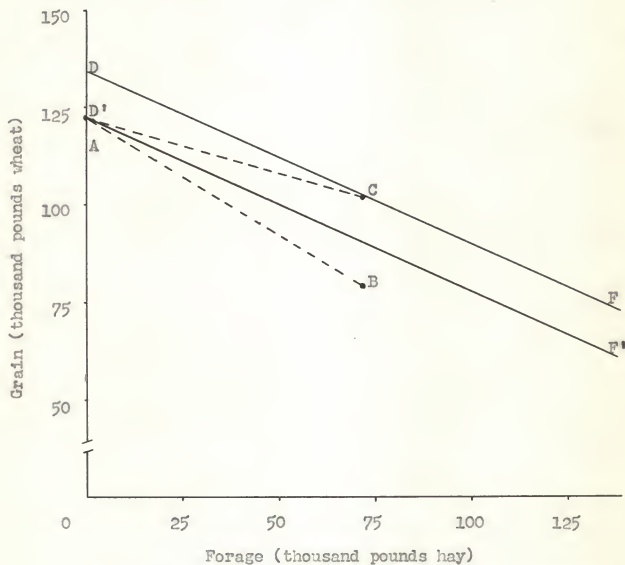


Fig. 8. Production possibilities under two rotations at Wichita, 1933-1950.

harvesting methods and sorghums handled as in the rotation will have a higher cost of production than continuous wheat. Alfalfa production costs are estimated in Table 18.

Table 18. Estimated production costs per acre for alfalfa, Reno County, Kansas.^a

<u>Tilling and seeding</u>		<u>Harvesting</u>	
Plowing	\$ 2.40	Mowing (3)	\$ 3.60
Discing (2)	2.50	Raking (3)	2.85
Harrowing (2)	1.00	Baling (2 tons or 66 bales)	10.56
Packing	1.25	Hauling and storage	
Drilling	1.00	(.05 per bale)	<u>3.30</u>
Seed (12 lbs.)	<u>2.98^b</u>		
Total tilling and seeding cost	\$11.13	Total harvesting cost	\$20.31
Net cost per acre -- stand left 2 years = \$25.88			
" " " "	" "	3 "	= 24.02
" " " "	" "	4 "	= 23.09
" " " "	" "	6 "	= 22.00

a 1952-53 Custom Rates for Farm Operations in Central Kansas. Kansas Agr. Exp. Sta. Report No. 60, Nov. 1953. Land costs are not included.

b Average price received by farmers, 1953, Agricultural Prices, Report of Federal-State Statistician, Topeka, Kansas.

Since alfalfa usually stands four years or longer in central Kansas, the alfalfa production cost may be considered as \$22 to \$23 per acre in most cases. Estimated cost of wheat production from Table 13 is \$12.85 per acre. These figures are admittedly only approximate. They represent a sort of opportunity cost, since a farmer who does his own work, and does not pay the custom price, might be earning such a price working

for another farmer, or in some other industry. They do compare closely to the cost figures in at least one other state.¹

No cost figures were available for the operations necessitated by the sorghum harvesting methods used in the rotation, but they would appear to be quite high. The greater harvesting costs of the rotation crops would cause the rotation to be less advantageous than it appears to be in Table 17.

Tests at Wichita also included a four year rotation, part of which was a study of the effects of sweet clover on wheat yield. An attempt was made to establish a stand of clover in the fall after wheat. In some cases it was necessary to replant in the spring and plow under several months later to maintain the crop sequence. While little or no pasture could be expected under such a system, the minimum amount of pasture estimated in Table 10 under such a system has been allowed in computing the gross value of crops in the clover rotation. In Table 15, comparison has been made of the clover rotation with untreated continuous wheat and with fertilized wheat.

Table 19 indicates less disadvantage to the production of sweet clover as a source of nitrogen than was shown at the Kingman Field. However, the necessity of imputing a value to the clover is as important at Wichita as at Kingman. If the clover were to be plowed under without being pastured, the gross return per acre to the legume rotation would be only \$34.35.

¹Earl O. Heady and Harald R. Jensen, The Economics of Crop Rotation and Land Use, Res. Bull. 383, Iowa Agricultural Experiment Station, p. 442.

Continuous wheat would offer a \$6.50 higher return per acre, an amount which would be charged as a cost on a farm where a clover rotation was used, and where this general relationship held. On some farms, this may be charged as a cost of conservation. The farmer's problem then would be to determine whether he could get an equal amount of conservation in some less expensive way. It would be a factor-factor problem, with the legume compared with mechanical or other means of conservation, considered as inputs for production.

Table 19. Yield and gross value per acre, above cost of fertilizer, of specified rotations, Sedgwick County, Kansas, 1933-1950.^a

Rotation	:Yield of: : wheat : per acre:	:Value of: : wheat : (\$2 bu.):	: Value of : : pasture : (\$3.21 AUM):	: Total: : value:	:Cash cost : : of : fertilizer:	: Gross : value : product
Cont. wheat	20.4	\$40.80		\$40.80	---	\$40.80
Cont. wheat (24 lbs. N.)	21.3	42.60		42.60	\$3.60	39.00
C1-W-W-W	22.9	34.35	\$1.20	35.55	---	35.55

a Nineteenth Annual Report, South Central Kansas Experiment Fields, Kansas Agricultural Experiment Station, 1950.

ROTATIONS IN NORTHEAST KANSAS

Data from extreme northeastern Kansas were limited to some rotations near McLouth in Leavenworth County, where the Northeast Kansas Experiment Fields were located from 1932 to 1942. This period coincides partially with the severe drought which affected crop yields in the whole Midwest.

Rainfall records were not available for the field where the rotations were conducted, but are presented in Table 20 for the recording station nearest the field.

Table 20. Rainfall amounts by years at Tonganoxie, Leavenworth County, Kansas.^a

Year	:	Inches	:	Year	:	Inches
1932		24.8		1938		31.5
1933		24.5		1939		27.8
1934		25.6		1940		46.0
1935		46.1		1941		45.6
1936		22.5		1942		38.1
1937		23.8				
Mean rainfall--1932-42--32.4 in.						
" " 1938-42--37.8 "						
Normal " 1932-46--35.0 "						

^a Climate of Kansas, Report of the Kansas State Board of Agriculture, June 1948.

Comparison of grain alone with an alfalfa rotation confirmed the previous conclusion that rates of substitution are relatively low in such rotations. Average rate of substitution, hay for corn, in the range 0-40 per cent alfalfa, was .34 for untreated rotations and .33 for manured rotations. This also substantiated the conclusions from Manhattan data that under fertilization, forages compete less advantageously with grain than they do without treatment.

Tables 21 and 22 give marginal rates of substitution and gross income comparisons between continuous grain and grain-alfalfa rotations, for several price relationships.

Table 21. Enterprise relationships and marginal rates of substitution for rotations at McLouth, Kansas, 1932-1942. Based on 100 acres of land.^a

	: Acres out	:	Production	:Marginal rate
	: of 100 in	:	(lbs.)	:of substitution
Rotation	:	:	:	:(lbs. grain
	: Grain	: Forage	: Grain ^b	:sacrificed per
	:	:	:	:lb. hay gained)

Untreated

C-O	100	0	100,240	0	.34
A-A-C-O-W	60	40	74,600	74,500	

Manure, average 2 tons annually

C-O	100	0	125,720	0	.38
A-A-C-O-W	60	40	78,232	124,100	

a Report of the Northeast Kansas Experiment Fields, Vol. I-XI.

b In corn equivalent, value of grain/price of corn, 1953 prices.

Table 22. Production and gross income of rotations at McLouth, Kansas, 1932-1942, under various price relationships.^a

Rotation	: Production		: Gross Income		
	: (lbs.)		:		
	: Grain	: Hay	: 1953	: 1950	: 1948

Untreated

C-O	100,240	0	\$2,631	\$2,327	\$3,347
A-A-C-O-W	74,600	74,500	3,113	2,511	3,307

Manured

C-O	125,720	0	\$3,301	\$2,918	\$4,198
A-A-C-O-W	78,232	124,100	3,977	2,945	3,971

a Production figures, Table 21, prices, Table 2.

Comparison of continuous grain with clover rotations indicated the presence of a complementary range at some level of legume production. However, it was apparent only in the corn-oats rotation in which a clover catch crop was grown.

This has been arbitrarily designated a 25 per cent legume rotation, although grain was grown each year. Presence of complementary effects from clover suggests that such effects probably exist in alfalfa production also, perhaps in the range 0-25 per cent alfalfa, as was suggested by the Manhattan data.

The complementary effect was no longer apparent when clover was allowed to occupy the land for a full year in the three year rotation (Table 23). However, in the period 1932-42, the drop in grain production was not large, while in the wet years of 1933-42 the grain loss was considerable.

Table 23. Production and gross returns for rotations at McLouth, Kansas, based on 100 acres of land.^a

: Acres in :		: Production :		: Gross income ^d :	
Rotation:	Grain :	Forage :	Grain ^b :	Forage ^c :	1953
<u>1938-42</u>					
C-0	100	0	124,380	0	\$3,265
C-0c1	75	25	134,850	25	3,631
C-W-C1	67	33	90,500	50	2,559
<u>1932-42</u>					
C-0	100	0	100,240	0	2,631
C-0c1	75	25	101,800	25	2,764
C-W-C1	67	33	93,460	50	2,636

a Report of the Northeast Kansas Experiment Fields, Vol. I-XI.

b In corn equivalent, value of grain/price of corn.

c Forage is in animal unit months, estimated from Table 10.

d Corn price, \$1.47 (Table 2), pasture valued at \$4.39 per acre, or \$3.66 per animal unit month, based on cash rental for pasture, Type of Farming Area 3, 1953, unpublished data, Department of Economics and Sociology, Kansas State College.

The comparative gross income estimates in Table 22 are at best only rough indicators of the relative profitability of grain or grain-hay rotations. As indicated previously in cost

of production estimates, (Tables 13 and 18), the cost of production of alfalfa may be considerably higher than that of grain under some methods of handling. Apparent advantage to forages may be negated were costs applied to Table 22. No attempt has been made to do this with the data.

Similarly, estimated rates of substitution between the two rotations in Table 21 do not account for cost differences, but only for technical substitution effects. Adjustment for added cost under many methods of handling hay would cause the legume rotation to appear less favorable than it appears in Table 21.

Cost of sweet clover production may be less than cost of grain production under some handling methods (Table 13). If so, such production would be more favorable than was estimated in Table 23.

THE SABETHA WATERSHED STUDY

Very little information was available in Kansas to indicate the extent to which farmers attempt to follow a specific rotation, and to indicate the degree of success they have in following the planned rotation.

However, a study in Northeastern Kansas offered some information on this problem. This project was under way at the time of this study. It is a broad study of technical and economic consideration affecting soil conservation and related problems

in the watershed of the Sabetha, Kansas, reservoir. Several public agencies are cooperating in the project.¹

A total of 5,790 acres was included in the watershed, exclusive of the reservoir, roads, and railroads. Of this an average of 4,503 acres was reported for crops, including tame grasses, during the period 1948-1953. Average acreages and percentage of cropland devoted to various uses are given in Table 24, along with one recommended future system for the area, which will be discussed later.

Of immediate interest to this study is the fact that of the 39 farms surveyed, 15 specified only one rotation for the farm. All of these took the general form of C-C-O-W-C1. Ten others listed a rotation for each field, while 14 did not specify any rotation, but did indicate a changing cropping sequence.

No attempt was made to analyze differences between plans and practices statistically. Some general comparisons are included in Table 25, indicating some very wide differences from intentions and some close conformation to plans.

It is notable that none of the planned rotations included any alfalfa. However, nearly all the farms produced alfalfa, and 6.8 per cent of all cropland was in alfalfa during the period. About 11.2 per cent of the cropland was in mixed grasses and legumes, and in most cases, did not enter into the

¹The information presented in this section about the project is derived from unpublished survey data of the Department of Economics and Sociology, Kansas State College, unless otherwise noted.

Table 24. Actual land use in the Sabetha Reservoir Watershed, 1948-1953 average, and a suggested future land use.

Land use--1948-1953 average		:	% of cropland in
		:	specific crops
Cropland	Acreage		
Corn	1,664		38
Small grain	1,533		34
Legumes and tame grasses	1,263		28
Sub-total--Cropland	4,460		100
Pasture, idle, farmsteads	1,330		
Total land	5,790		
<u>Recommended future land use^a</u>			
Cropland			
Corn	1,460		32
Small grain	960		21
Legumes and tame grasses	2,160		47
Sub-total--Cropland	4,580		100
Pasture, idle, farmsteads	1,210		
Total	5,790		

a Advance Report on the Sedimentation Survey of Sabetha City Reservoir, Sabetha, Kansas, United States Department of Agriculture, Soil Conservation Service, Lincoln, Nebraska, August 1952, Table 7.

rotation. Clovers were the only soil conserving crops being used regularly in rotation by farmers in the area studied, while alfalfa appeared to have been grown on selected fields. Clovers occupied an average of 10 per cent of the cropland during the period, or 15 per cent short of the approximate limit of the complementary range suggested previously as existing in one location in Northeastern Kansas when no fertilizers were used. As discussed previously, this complementary range may be shortened, or perhaps eliminated when fertilizers are used as substitutes for a legume rotation, or when mechanical methods of conservation substitute for organic methods.

Table 25. Rotations, grain and forage percentages planned, and actual grain and forage percentages on 15 farms in the Sabetha Reservoir Watershed.

Farm ^a	Rotation indicated	Grain and forage : percentages planned		Grain and forage : percentages practiced ^b	
		Grain	Forage	Grain	Forage
1	C-C-O-W-C1	80	20	68	32
3	C-C-O-C1-W	80	20	63	32
4	C-C-O-W-C1	80	20	85	15
5	C-C-O-W-C1	80	20	76	24
8	C-C-O-W-C1	80	20	74	26
11	C-C-O-W-C1	80	20	83	17
12	C-C-W-C1	75	25	73	27
15	C-C-O-W-C1	80	20	77	23
17	C-C-O-W-C1	80	20	62	38
22	C-C-O-W-C1	80	20	86	14
25	C-C-O-Wcl	100	0	100	0
30	C-O-W-C1	75	25	100	0
36	C-C-O-W-C1	80	20	44	56
38	C-C-O-W-Legume	80	20	46	54
39	C-O-W-C1	75	25	100	0

a Farm numbers are from the original survey by the Department of Economics and Sociology, Kansas State College, made in 1953.

b 1948-1953 average.

Many of the farmers in the watershed indicated in the survey that they used fertilizers of some type. Over 90 per cent of the farm owners and operators have agreed to apply conservation practices on their farm.¹ Soil maps indicate that a great deal of progress has been made in building terraces and other mechanical conservation structures. To the extent that fertilizers and other rotation substitutes already exist or are

¹Advance Report on the Sedimentation Survey of Sabetha City Reservoir, Sabetha, Kansas, United States Department of Agriculture, Soil Conservation Service, Lincoln, Nebraska, August 1952, p. 8.

planned, farmers may be expected to offer considerable resistance to educational efforts to encourage increased production of forage crops to an extent beyond the complementary range existing on individual farms with a given use of such rotation substitutes.

Such farmers have, in effect, made a factor-factor decision involving substitution ratios and price ratios between legumes and terraces as inputs in the production of soil conservation. Farmers who, before terracing, could logically charge income sacrificed in producing a large proportion of clover, to the cost of conservation, can no longer make such an imputation after terracing. The conservation value of the forage may be negligible in the presence of terraces, compared to such value before terraces were built.

Rotations and Prices

Some idea of farmers' response in adapting their cropping system to changing relative prices may be gained from the Sabetha Watershed data. A great many other factors whose effect cannot be evaluated here also play a part in production changes.

In Table 26, the ratio of wheat acreage to corn acreage moves in the same direction as the ratio of wheat to corn price in all years except 1952. In 1952, the wheat/corn acreage ratio rose, even though wheat was relatively unfavorably priced compared with 1951.

Alfalfa acreage experienced an absolute decline in the period studied of nearly 100 per cent while wheat acreage was

rising. This accounts for the wide range of the wheat/alfalfa acreage ratio in Table 26. The price ratio wheat/alfalfa may have been a causal factor since its initial direction corresponds to the initial direction of the acreage ratio. However, other factors appear to have outweighed primary product price considerations in 1952 and 1953. These factors may have been climatic, since some drought was felt in Kansas in 1952. An important consideration may have been the extreme drop in the price of cattle, the most important secondary product of forages such as alfalfa.

Table 26. Crop acreage adjustments as related to changes in relative prices, Sabetha Reservoir Watershed, 1948-1953.^a

Year:	(P)W/(P)C ^b	(A)W/(A)C	(P)W/(P)Alfalfa	(A)W/(A)Alfalfa
1948	1.12	.38	.095	1.4
1949	1.63	.50	.104	2.6
1950	1.51	.49	.103	2.8
1951	1.35	.45	.091	2.4
1952	1.27	.52	.063	4.4
1953	1.36	.62	.065	3.9

a 1948-1952 price ratios were computed from monthly average prices received by farmers, Annual Report of the Kansas State Board of Agriculture, Topeka, Kansas, 1943-1952. Prices for 1953 were computed from mid-month average prices received by farmers reported in Agricultural Prices, monthly report of the Federal-State Statistician, Topeka, Kansas.

b P = price, W = wheat, C = corn, A = acreage. Prices are in bushels grain or tons hay.

Policy Considerations

It is not surprising that the proposed land use pattern in Table 24 stresses what are commonly called soil-saving crops, with 47 per cent of the acreage being so allocated,

compared with the 1948-53 average of 23 per cent. This is as expected because the problem being studied by the agency which made the recommendation is primarily a runoff and siltation problem. The use of soil saving crops is known to retard erosion and runoff, and to inhibit siltation of reservoirs. The use of such crops is also known to have beneficial effects upon the soil, and ultimately, if it is to be justified to the farmer, it must have the same effect on his income.

The question of who is to receive and who is to pay for the direct and indirect benefits of a cropping program such as proposed in Table 24 is an important policy problem, and is inevitably in the farmer's mind as he makes his decisions concerning conservation on his farm.

If the analysis of the rotations in Northeast Kansas is operational, it is likely that the direct cost of a land use program such as proposed in Table 24 will be borne by the farmer in the short run. Income sacrifice under all but the most favorable forage prices would be considerable in the early years of operation, and may continue even after the effects of the legumes were felt on grain yields. The proposed land use program presupposes a further production adjustment, to increased livestock on farms. On farms not making such an adjustment, income loss might be continuous, on others it could be terminated and eventually reversed by livestock income.

This appears to justify the policy of incentive payments to farmers to encourage them to produce soil conserving crops.

Such payments have been made, in the past, by the federal government.

In a localized situation, such as a watershed, it is conceivable that a small legal entity, such as a city, a county, or even a business firm, might engage in the payment of incentives to farmers to encourage the land use program which will benefit the paying agency directly, but which at the same time, will be disadvantageous to the farmer.

On a national scale, it would appear logical to make such payments to advance social goals, such as conservation, but only to the extent that the discounted returns from such practices were less than the returns from previous practices. Payments may be justified, even to farmers who can enjoy the complementary effects of legumes, but only during the time needed to make such effects felt, not to maintain them.

TIME, DISCOUNTING, AND RELATED FACTORS

The production estimates, gross income estimates and marginal rates of substitution in the preceding pages have all been predicated on the assumption of timelessness. That is, it was assumed that no time need be spent in waiting for the fruits of an action, and that they accrue to the actor instantaneously and steadily at some known rate. Obviously, this is unreal.

Income resulting from the joint products of legume rotations is realized over a considerable time. Since future income, in the presence of uncertainty, is relatively less desirable

than present income, such future income streams must be discounted at some rate, depending on the capital situation of the operator. Since capital is known to be highly productive on many farms, this discount rate must be very high on such farms. Its effect will be to lower the subjective present value of future income increases, to negate such increases in some cases, or to make the undesirable alternative appear even less desirable.

In Table 23, the annual gross value of a C-W-C1 rotation was calculated using 1953 prices. The legume rotation appeared to have a slight advantage over a C-O rotation on the basis of the estimates. However, when both income streams were discounted, using the formula, $V = I_1 + I_2/(1 + r) + I_3/(1 + r)^2 + \dots + I_n/(1 + r)^n$, the present value of income expected over three years was \$7,523 for the non-legume rotation, and \$7,392 for the legume rotation.¹ This was an exceptionally short legume rotation. It may be seen that a longer rotation postpones grain yield increases even longer, and that the discounted value of such increases may become very low. Use of a 20 per cent rate, which may be realistic for some farmers, caused the legume rotation to appear even less favorable, its value for three years falling to \$6,171, while the continuous grain rotation discounted to \$6,651.

Kingman data offer another example of such procedure. Here (Tables 8 and 9) continuous wheat appears to have an

¹ V = present value, I = income, r = rate of interest.

advantage over a 25 per cent clover rotation, of about six bushels of wheat per acre in four years. When the yield increases were discounted at the market rate (.05), this advantage went to 7.1 bushels, increasing the value deficit of the clover rotation. This must be made up by the value of clover forage or seed if the rotation is to be adopted and made profitable.

Long and Short Run Production Possibilities¹

Farmers have other important reasons for resisting efforts to have them change the pattern of their production. One of these is the fact that once they have committed their capital to a certain use, they have, in the short run, given up some production opportunities which once existed for them.

The transformation functions which have been estimated previously have been long run functions. The yield increasing effects of the joint products of legumes were assumed to be present at the beginning of the period, which is not true for most farmers.

A transformation function such as was estimated in Fig. 7 is a long run or planning curve. A farmer whose resources are committed to wheat can produce at point A, but he cannot reach other points on the curve immediately, because his yields will not be those presupposed by the transformation function. Heady's hypothesis suggests that in the short run the production possibilities will be similar to those shown by AI in Fig. 9.² This

¹Heady, op. cit., Ch. 9, includes a discussion of this nature. Principles used here are based on Heady's discussion.

²Ibid., p. 279.

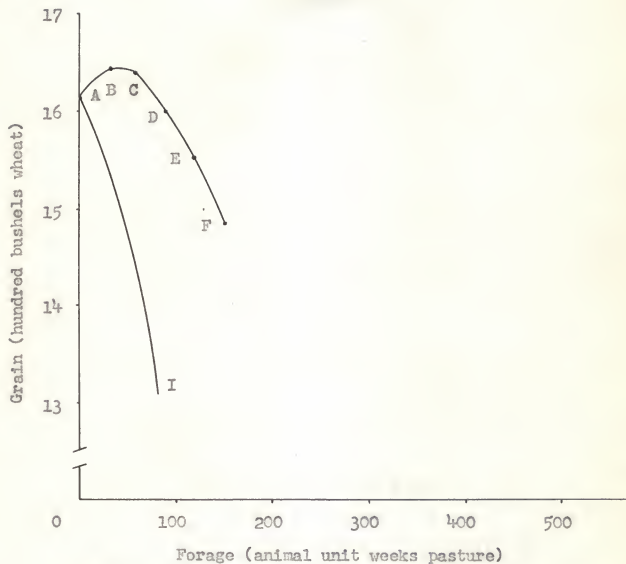


Fig. 9. Estimated long run and short run transformation functions.

will be true, not only because of yield response, but because machinery limitations, farmer skills and other factors will combine to cause the net short run production to be lower than that technically possible in the long run.

Rotation recommendations, in normal times and in quasi-emergencies, such as times of acreage control, should be tempered by recognition of these facts.

Recommendations that the pattern of production and resource use which maximizes profits (or conforms with other choice indicators) on one farm should be employed on a second farm may be erroneous if the structure of short run production opportunities is not recognized by the research worker or educational expert in his suggestions to farmers.¹

Another factor that farmers might well consider in making production decisions concerning use of legumes is the finality or irreversibility of organic nitrogen production. A farmer who has produced a leguminous crop has committed himself to supplying supplemental nitrogen to grain crops following the legume. He cannot decide to withhold it in an extremely dry year when it may reduce his yields rather than raise them. Nor can he decide to invest his nitrogen dollar in another factor of production, even though it appears that the return to capital so invested will be far above the return to nitrogen.

Rotations and Tenure

Reference has been made to the fact that rotation relationships exist only over time. In any one year all crops are

¹Ibid., p. 232.

competitive. This is especially important to tenants, and to owners short on capital. Such operators, when faced with production alternatives requiring varying lengths of time for full realization, must inevitably discount the remote income at a high rate, due not only to their capital position, but to the subjective uncertainty of the future production. Farmers with short tenure expectations cannot average future expectations, because they have so little knowledge about their future.

The effect is to necessitate use of an almost infinite rate of interest in discounting future returns. Even short legume rotations, such as shown in Table 23, offer little incentive to many tenants or part owners, to whom present income from a given farm is almost infinitely more valuable than anticipated future income. This would appear to lead to potentially serious land resource misallocation, when the product of short term decisions is viewed against the product theoretically attainable in a longer time period. However, there is no assurance that a share tenant, even though he viewed the future most optimistically and had a lifetime lease, would ever produce the combination of crops which would meet the requirements of technical, economic, or social efficiency.

Rather, a tenant who by the nature of his rental agreement, normally adds labor and capital to a given amount of land, will solely in his own interest, attempt to operate in such a manner that the marginal return to the factors he provides is at or near a maximum. By definition, he would then be operating at the

point where the marginal return to land was lowest, or approaching a minimum.¹

Such attempts must necessarily be based on subjective factors also. One of these factors is the tenant's discount rate. Even though one tenant operator may decide that his goals regarding returns to the factors he provides (discussed previously) are met at some certain combination of crops, another such operator under identical physical circumstances might find it necessary to choose some other crop combination due to subjective or actual discount rate differentials.

The uncompromised interest of the land owner is similar to that of the tenant. If labor (or tenants) were plentiful and landowners held the sole bargaining position, it would be to their advantage to insist on a system which would maximize the return to land and minimize the return to labor. The classic example of such an arrangement is that of corn cultivations, which cost the owner nothing, although he shares in the marginal product of the operation.

Obviously, neither tenants nor owners may view their interest separately. Each operates, to some degree, a monopoly. Land is scarce, therefore valuable, but so are tenants. While a tenant's short term interest may tend toward some organizational plan, it also includes a psychological and financial aversion to moving to a new farm. An owner's short term interest is similar

¹D. Gale Johnson, "Resource Allocation Under Share Contracts," The Journal of Political Economy, April 1950, 58:116.

since it costs money to find a new farmer, just as it costs a tenant to find a new farm.

With these facts in mind, tenants and owners undoubtedly compromise their interests in such a manner that the marginal rate of substitution between the conflicting technical interests (d tenant's interest/d owner's interest) is equal (tangent) to the marginal rate of substitution between the tenants and owners subjective and financial bargaining power (represented by a value line indicating the relative degree of insistence on the part of tenant and owner). This says simply that the nature of the cropping system followed depends upon the intensity of the financial and subjective time preference factors which make up the relative bargaining power of tenant and owner.

As Johnson pointed out, one of the main elements of owner bargaining power is the short term lease. He concluded tentatively that the short term crop share lease tended to create conditions which resulted in fairly efficient use of land resources, by adding to the owner's bargaining power.¹

A major problem with respect to rotations on rented farms is that of compensation to a departing tenant for unexhausted soil improvements made through the rotation. Such a situation is difficult to anticipate. After it arises, the tenant has little bargaining power to influence the adjustment. To the extent that the adjustment can be pre-arranged, tenants may tend to be able to plan rotations which look ahead to increased

¹Ibid., p. 122.

yields with less chance of loss of the postponed income.

SUMMARY AND CONCLUSIONS

The agronomic basis for crop rotation is well known, and has only been mentioned in this study. Some economic principles of crop selection have been presented. Soil conservation has also been briefly mentioned. However, discussion of conservation motives for crop rotation embraces a whole new discipline. The ethical basis for conservation, and therefore for legume rotations, is a study in philosophy, and has been omitted by necessity.

Cropping recommendations to Kansas farmers, especially in the eastern half of the state, have been, historically, to grow more legumes and less grain. This has tended to ignore the fact that such rotations might decrease income for many farmers in the time period they consider. In short, such advice has not been oriented toward the goals of all farmers. It reflected goals somewhat commonly held, but by no means unanimous.

The concept of opportunity cost is a valuable aid in the determination of the optimum cropping system on a farm, or in an area. Estimates of alternative production possibilities have been made here, and may be made rather simply by farmers in reaching production decisions using the opportunity cost concept.

In general, undiscounted future returns from alfalfa-grain rotations have appeared relatively favorable, as shown

by low marginal rates of substitution at the level of one-fourth of all cropland in alfalfa.

Less valuable, or less productive, legumes such as the clovers, have appeared less advantageous when in similar proportion with grains. There is some evidence that they have a place on some farms, but that they should be produced on a very small proportion of cropland on most farms.

The remote realization of the increased yields due to rotation is a strong deterrent to the adoption of legume rotation. Capital shortage and tenure uncertainty accentuate this unwillingness to postpone income, as shown by the small proportion of cropland in legume crops despite education for increased acreages.

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BIBLIOGRAPHY

Books

- Bailey, L. H., editor. Cyclopedia of American Agriculture. New York: F. S. Crofts and Company, 1925.
- Black, John D., and others. Farm Management. New York: The Macmillan Company, 1947.
- Gras, N. S. B. A History of Agriculture in Europe and America. New York: F. S. Crofts and Company, 1940.
- Heady, Earl O. Economics of Agricultural Production and Resource Use. New York: Prentice-Hall, 1952.
- Hopkins, Cyril G. Soil Fertility and Permanent Agriculture. Boston: Ginn and Company, 1910.
- United States Department of Agriculture. Soils and Men. Washington: United States Government Printing Office, 1938.

Periodical

- Johnson, D. Gale. "Resource Allocation Under Share Contracts." The Journal of Political Economy, April, 1950, 58: 111-123.

Government and State Bulletins

- Agricultural Prices. Monthly Report of the Office of the Agricultural Statistician. Topeka, Kansas, 1953.
- Annual Report of the Northeast Kansas Experiment Fields. Kansas Agricultural Experiment Station, 1932-1942.
- Annual Report of the South Central Kansas Experiment Fields. Kansas Agricultural Experiment Station, 1933-1951.
- Bieberly, F. G., E. A. Cleavinger, and L. E. Willoughby, Point Your Farm to Balanced Production. Kansas State College Extension Service Circular 200.
- Cleavinger, E. A., and L. E. Willoughby. Sweet Clover in Kansas. Kansas State College Extension Service Circular M-49.

Cleavinger, E. A., and others. Profitable Farm Practices. Kansas State College Extension Service unnumbered publication.

Friesen, M. J., C. F. Bortfeld, and J. A. Hodges. 1952-53 Custom Rates for Farm Operators in Central Kansas. Kansas Agricultural Experiment Station Agricultural Economics Report Number 59. 1953.

Heady, Earl O., and Harald R. Jensen. The Economics of Crop Rotation and Land Use. Iowa Agricultural Experiment Station Research Bulletin 383. 1951.

Kansas State Board of Agriculture. Climate of Kansas. Topeka: State Printing Office, 1948.

. Kansas Crop and Livestock Statistics. Topeka: State Printing Office, 1948-1952.

. Thirty-Sixth Biennial Report. Topeka: State Printing Office, 1948.

. Thirty-Seventh Biennial Report. Topeka: State Printing Office, 1950.

Throckmorton, R. I., and F. L. Duley. Twenty Years of Soil Fertility Investigations. Kansas Agricultural Experiment Station Technical Bulletin 40, 1935.

United States Department of Agriculture. Advance Report on the Sedimentation Survey of Sabetha City Reservoir, Sabetha Kansas. Soil Conservation Service, Lincoln, Nebraska, 1952.

Willoughby, L. E., F. G. Bieberly, and E. A. Cleavinger. Agronomy Handbook for 4-H Clubs. Kansas State College Extension Service Circular 197, 1948.

Newspapers

"Leaders of the Year." Feature Story. Kansas Farm Bureau News. December, 1953, p. 10.

Other Sources

Hobbs, J. A. The Effect of Crop Rotations and Soil Treatment on Soil Productivity. Contribution Number 498, Department of Agronomy, Kansas Agricultural Experiment Station, 1953.

Jones, H. E., O. W. Bidwell, and J. A. Hobbs. Lecture Notes for Soil Management. Agronomy Department, Kansas State College, 1952.

Thompson, W. N. Systems of Farming Adapted to Highly Productive Level Land in Illinois. Unpublished Ph.D. Thesis. University of Illinois, 1952.

AN ECONOMIC ANALYSIS OF SOME
KANSAS CROP ROTATIONS

by

JOHN ALVIN SCHNITTKER

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Recommendations to farmers in eastern and central Kansas concerning cropping systems have consistently pointed out the merits of crop rotations, particularly of legume rotations. The fact that certain crop rotations might possibly cause reductions in income, immediately and over some time period, has seldom been admitted.

Rotation recommendations have tended toward a preoccupation with yield per acre, without due regard toward production per farm. They have stressed the income increasing effects of rotations in some instances to the neglect of the fact that the increases will be effected in some remote time period, if they are realized at all, and must be discounted, perhaps at a high rate, due to uncertainty of production and tenure, and to the capital peculiarities of agriculture.

Discounting, even at market rates of interest, may have the effect of negating the present value of future increased income streams, and of destroying the incentive to attempt to earn the income increases. Since earnings on capital are known to be high in agriculture, discounting is often necessary at a rate well above the market rate.

The method employed in the analysis of rotations has been to consider as the cost of production of one commodity, the amount or value of another commodity that could not, therefore, be produced with the same factors at the same time. This is called the concept of opportunity cost.

Data from Manhattan for several time periods indicated relatively low rates of substitution of hay for grain in going

from continuous grain crops to several levels of alfalfa in the rotation. Comparison of continuous wheat with a 16 year alfalfa-grain rotation indicated that complementarity may exist between grain and alfalfa somewhere between the point where no alfalfa is grown and where alfalfa occupies one-fourth of the cropland.

Data from fertilized plots at Manhattan showed that the complementary range either was shortened considerably or did not exist under treatment, indicating that the effects of rotation were only partially additive to the effects of fertilization.

Sweet clover rotations at Manhattan appeared to be relatively less favorable than alfalfa rotations.

At Kingman, sweet clover rotations with oats and wheat were sharply less productive than continuous wheat. Comparison of the clover rotations with continuous wheat treated with commercial nitrogen indicated an excessively high cost of the organic nitrogen. Data were not available to compare treated rotations with the fertilized continuous wheat.

Data from Wichita, while somewhat complicated by a long rotation including a forage sorghum, appeared to substantiate the conclusion of the Manhattan data, that a rotation including up to one-fourth alfalfa may be relatively favorable, reflecting a low marginal rate of substitution.

Clover rotations at Wichita did not show the disadvantage apparent at Kingman. However, the increased yield of grain was not sufficient to justify non-utilization of clover forage.

In Northeastern Kansas, data from McLouth indicated the presence of complementary effects of catch crop clover, effects which were no longer present when clover replaced grain for a year in the rotation. Rates of substitution, hay for grain, in an intensive alfalfa rotation, were similar to those at Manhattan.

A perfunctory analysis of the results of a survey of farmers in a northeastern Kansas watershed indicated a considerable tendency toward following some legume rotation scheme. However, only clovers held a consistent place in the rotation. Clovers occupied only about 10 per cent of the cropland, even though many farmers indicated intentions to produce 20 to 25 per cent clover in a four or five year rotation. This suggests that farmers either do not know that they might produce more grain at a higher level of legumes, or that they actually cannot do so on their farm, given its fertility and state of conservation.

Other limitations to adoption of rotations include the fact that once resources are committed to some productive pattern on a farm, as they are on operating units, the production possibilities in the decision making time period are not those defined by the average yields at various combinations of grain and legumes, but are something less than those figures over a considerable time period.

The fact that organic nitrogen in the soil is a committed resource is also a limitation. A farmer cannot decide not to apply it in a dry year, when it appears that nitrogen will be ineffective or harmful. An under capitalized farmer cannot

decide to withdraw or refrain from investing in nitrogen on short notice if he already has it in the soil, even though he knows he could earn more by investing in some other factor of production.

Legume rotations are undoubtedly valuable to many farmers for various reasons. But the decision to adopt a rotation is dependent on many factors, not simply on technical considerations. Even though a legume appears to be technically advantageous, it may actually be economically unsound for many farmers, when seen in the framework of their capital situation, their current operational structure, and their personal goals.